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MOHAMED DOUCH

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Dédicace

Al Hamdou Lilah Ouahdah ...

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ
ٱقْرَأْ بِٱسْمِ رَبِّكَ ٱلَّذِى خَلَقَ ① خَلَقَ
ٱلْإِنسَٰنَ مِنْ عَلَقٍ ② ٱقْرَأْ وَرَبُّكَ
ٱلْأَكْرَمُ ③ ٱلَّذِى عَلَّمَ بِٱلْقَلَمِ ④ عَلَّمَ
ٱلْإِنسَٰنَ مَا لَمْ يَعْلَمْ ⑤ كَلَّآ إِنَّ ٱلْإِنسَٰنَ

Au nom d'Allah, le Tout Miséricordieux,
le Très Miséricordieux.
Lis, au nom de ton Seigneur qui a
créé, qui a créé l'homme d'une adhérence.
Lis ! Ton Seigneur est le Très Noble,
qui a enseigné par la plume [le calame],
a enseigné à l'homme ce qu'il ne savait pas...
Al-Alaq versets 1-5

Je dédie cette thèse

À mes parents pour qui aucun mot ne serait
témoigner de ma gratitude et ma reconnaissance.
Je souhaite qu'Allah leurs préserve une longue vie,

À mes frères et mes sœurs
Pour leurs encouragements et leurs affections,

À Nadia
Pour son soutien moral,

À tous mes ami(e)s,

À vous tous, un Grand Merci tout en vous souhaitant un avenir plein de santé, de joie, de bonheur et de succès.

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RÉSUMÉ

La présente thèse porte sur l'étude de plusieurs sujets en macroéconomie monétaire et financière. En effet, notre analyse va se pencher sur des questions qui restent sans réponse dans la littérature et parfois pousser l'analyse plus loin que ce qui est déjà fait. Cette thèse se compose de trois essais.

Le premier chapitre, qui s'intitule «*Equity Premium In a Small Open Economy*», étudie le comportement de la prime d'équité dans une petite économie ouverte. Les modèles du cycle réel (RBC) bien qu'ils arrivent à expliquer la dynamique du cycle économique et à reproduire les caractéristiques des variables macroéconomiques, échouent toutefois à reproduire les faits stylisés concernant les prix des actifs. La modification de la fonction d'utilité pour tenir compte des habitudes de consommation des agents ainsi que l'incorporation de coût d'ajustement du capital arrivent à résoudre ce problème dans un cadre d'analyse d'économie fermé. Nos résultats montrent que ce type de modèle génère une faible prime de risque une fois que le cadre d'analyse d'économie ouverte est utilisé, et ce, comparativement à la prime observée dans les données historiques. Cet échec peut être attribuable au fait que les ménages domestiques peuvent jouer sur le lissage de leur consommation avec l'accès aux marchés financiers internationaux.

Le deuxième chapitre, qui s'intitule «*Monetary Policy, Financial Crisis and Effects on Real Economy*», étudie le comportement des chocs monétaires combinés à des perturbations financières et leurs effets sur l'économie, et surtout, le volet réel de celle-ci. On examine alors l'exogèneité des chocs de politique monétaire et des crises sur le marché boursier pour analyser par la suite l'impact des deux perturbations et leurs implications sur les variables macroéconomiques. Nos résultats montrent, selon toute évidence empirique, que les deux types de chocs sont exogènes pour démontrer par la suite que ces perturbations ont des effets significatifs sur l'activité économique réelle.

Pour conclure, on s'est penché dans le dernier chapitre intitulé « *Hybrid Inflation-Price-Level Targeting in Small-Open-Economy New-Keynesian Framework* », sur les règles de conduite de politique monétaire en petite économie ouverte. C'est ainsi qu'on s'est arrêté dans cette étude sur les conséquences de diverses règles de conduite de la politique monétaire, en se préoccupant plus de la règle hybride qui vise la stabilité des prix en ciblant en même temps un niveau général des prix combiné à un taux d'inflation prédéterminé. Nos résultats montrent que le modèle hybride peut donner une bonne alternative aux régimes ciblant uniquement le taux d'inflation ou le niveau des prix, sans une perte majeur au niveau du bien-être économique.

Mots Clés : Prime d'Équité, Formation d'Habitude, Chocs Monétaires, Politiques Monétaires, petite économie ouverte, Modèle d'Équilibre General.

ABSTRACT

This thesis consists of three essays on various monetary and financial topics and sheds new light on some questions that are still ambiguous or have not yet been explored in the literature.

Chapter I focuses on the behavior of asset prices in relation to consumption and other business cycle variables. While RBC models have been able to successfully explain the dynamics of macroeconomic variables, they fail to replicate similar interesting stylized facts when studying the behavior of asset prices. In an attempt to solve this shortcoming, some progress has been made in models that modify utility in order to account for habit persistence and incorporate capital adjustment costs. We have developed a framework that combines these ingredients by applying the loglinearly reduced form of the general equilibrium model and the asset pricing formula, based on the lognormality of the disturbance distribution for the small open economy case. Our findings indicate that in a small open economy environment this kind of model fails to account for a substantial equity premium.

In Chapter II, we focus on postwar US data and incorporate new financial measures and monetary policy shocks in a vector autoregression (VAR) system in order to test whether one or the other has any real effect on the economy. We find econometric evidence that these shocks and events are exogenous, and therefore the exogenous nature of shocks to monetary policy and stock market crashes investigated in this study may help policymakers, especially regarding debates related to eventual relationships between optimal monetary policy and financial stability.

Finally in Chapter III, we use a small open economy version of the Calvo sticky price model to investigate hybrid inflation/price-level targeting. We explore the proprieties of this kind of targeting regime within a calibrated structural general equilibrium model. We also consider monetary policy in terms of Taylor interest rate rules and conduct a welfare analysis on various specifications. Our analyses show that hybrid targeting performs well and produces quantitatively good results, compared to those regimes that target only price levels or inflation rates. A hybrid regime thus appears to provide a successful method for conducting monetary policy in a small open economy.

Keywords : Equity Premium, Habit Formation, Monetary shocks, Monetary Policy, Small Open Economy, General Equilibrium Model.

INTRODUCTION GÉNÉRALE

Les modèles d'équilibre général dynamiques se sont avérés appropriés et utiles pour l'étude des interactions économiques entre les marchés et les agents dans un cadre d'analyse macroéconomique de plus en plus complexe. En effet, les travaux de Kydland et Prescott (1982) et de Long et Plosser (1983) ont servi à la construction de plusieurs modèles ayant pour objectif de base l'analyse du cycle économique.[1] Toutefois, l'incapacité des modèles RBC à reproduire certaines caractéristiques essentielles du cycle économique a suscité l'avènement de modèles qui intègrent des frictions tant au niveau du marché du travail que du marché des biens et services.

Ainsi, on a assisté durant les deux dernières décennies à l'avènement d'une panoplie de méthodologies qui ont essayé de remédier aux imperfections de ce type de modèle. Dans ce sens, on a essayé de résoudre l'un des échecs des modèles RBC et peut être le plus important qui demeure celui de la modélisation des prix des actifs. Bien que des essais aient été menés pour résoudre cette imperfection, la modélisation du fonctionnement du marché financier a été ignorée ou tout simplement mise de coté par les modèles RBC qui n'arrivent pas à donner des explications satisfaisantes aux faits stylisés concernant les rendements des actifs financiers.

En outre, les modèles d'équilibre général dynamique sont aussi utilisés dans l'étude des politiques monétaires. Ces études visent plus particulièrement à cerner leurs implications sur le reste de l'économie et ainsi produire de bonnes prédictions quant à la politique optimale à suivre par les autorités monétaires. Pour ce faire, plusieurs auteurs prônent des considérations empiriques et théoriques instructives des forces et des faiblesses de ce type de modèle pour construire leurs résultats. Ce qui a permis d'enrichir la littérature par des contributions méthodologiques qui parfois arrivent à résoudre cer-

[1] Les modèles du cycle réel (RBC) sont les plus étudiés dans ce genre de littérature.

taines énigmes du passé (Calvo, 1983, Yun, 1996 et Clarida et al. 1999 pour ne citer que quelque uns).

Cette thèse, laquelle est constituée de trois essais, se situe dans ce cadre d'analyse. En effet, notre analyse va se pencher sur des questions qui restent sans réponse dans la littérature et parfois pousser l'analyse plus loin que ce qui est déjà fait. On a donc utilisé un cadre d'analyse d'équilibre général pour explorer, dans un premier essai, les modèles traitant les prix des actifs dans un environnement de petite économie ouverte, pour ensuite étudier, dans un second essai, le comportement des chocs monétaires combinés à des perturbations financières sur l'économie et surtout sur le volet réel de l'activité économique.

On se penche, dans un troisième essai, sur les règles de conduite de politique monétaire en petite économie ouverte. C'est ainsi qu'on s'est arrêté dans cette étude sur les conséquences de diverses règles de conduite de la politique monétaire, en se préoccupant plus de la règle hybride qui vise la stabilité des prix en ciblant en même temps un niveau général des prix combiné à un taux d'inflation prédéterminé. On analyse alors plusieurs questions que pose la conduite de la politique monétaire dans un tel cadre. Plus précisément, on examine diverses règles en comparaison avec la règle hybride que peuvent suivre des autorités monétaires déterminées à assurer la stabilité des prix.

Ainsi, dans le premier essai, on s'intéresse à la modélisation du comportement des rendements des actifs financiers. Cette question a suscité beaucoup d'intérêt au cours des dernières années. Le modèle de dotation de Lucas (1978) a donné suite à une littérature abondante traitant les relations entre fluctuations économiques et rendements des actifs, ce qui a aboutit à plusieurs controverses.

La question principale de toutes ces études est de concilier les données et la théorie économique et donc de construire des modèles avec processus endogènes pouvant générer ce qu'on observe au niveau de ces données. En effet, les données (tirées des bases de données des pays industrialisés pour la période d'après-guerre) montrent par exemple que la consommation est lisse et, par conséquence, que la covariance entre les rendements des actifs et la consommation est faible. Or, dans les modèles des prix des actifs basés sur la consommation introduits par Hansen et Singleton (1983), la quantité du risque du marché financier est mesurée par la covariance entre le rendement excédentaire des actifs financiers et le taux de croissance de la consommation, tandis que le prix du risque est mesuré par le degré d'aversion pour le risque de l'investisseur. Le rendement moyen élevé des actifs risqués et le bas taux d'intérêt sur les actifs sans risque (faits stylisés) implique donc que le rendement excédentaire espéré sur les actifs risqués (la prime d'équité) est élevé. La consommation étant lisse, la prime d'équité peut être expliquée seulement si on suppose un coefficient d'aversion pour le risque de l'investisseur excessivement élevé, d'où l'énigme.

Plusieurs études ont essayé de résoudre cette énigme en introduisant une classe de fonctions d'utilité avec formation d'habitude (Abel, 1990 et Constantinides, 1990). Le succès relatif de ce type de fonction d'utilité réside dans le fait qu'elle génère une variabilité excessive de l'utilité marginale de la consommation, d'où une covariance élevée entre cette utilité marginale et le rendement excédentaire des actifs risqués. En conséquence, la prime d'équité est expliquée sans recours à un coefficient d'aversion élevé.

Cependant, Rouwenhorst (1995) conclut que dans le cadre d'une économie fermée expliquer une prime de risque substantielle est difficile à cause du lissage de la consommation par les agents quand le degré d'aversion pour le risque augmente. Les agents économiques dans ce cas peuvent facilement changer leurs plans de production et faire face aux fluctuations de leurs consommations (Jermann, 1994) ; cela implique que c'est l'ajustement du stock du capital qui est à la source de cette faiblesse dans ce genre de modèle. L'introduction de coûts d'ajustement du capital peut toutefois résoudre ce problème et, avec une bonne spécification de la fonction d'utilité, on peut arriver à capter la prime d'équité et même à résoudre son énigme (Jermann, 1998).

Les résultats obtenus dans notre étude montrent que le modèle avec un secteur de production et une fonction d'utilité caractérisée par une formation d'habitude et un coût d'ajustement pour le capital ne peut pas expliquer la prime d'équité dans une petite économie ouverte. En effet le modèle génère une faible prime comparée à celle observée dans les données historiques. Cet échec peut être attribuable au fait que les ménages domestiques peuvent jouer sur le lissage de leur consommation, avec l'accès aux marchés financiers internationaux. Dans ce cas-ci, l'ajout substantiel apporté au modèle RBC standard par la formation d'habitude et les coûts d'ajustement du capital sera contré par l'ouverture de l'économie sur les marchés financiers internationaux. D'où le fait que le succès relatif obtenu par Jermann (1998), Benninga et Protopapadakis (1990), Danthine et al. (1992) et Rouwenhorst (1995) ne soit possible qu'en économie fermée. Le modèle arrive toutefois à bien expliquer les statistiques du cycle économique et à reproduire des résultats similaires à ceux obtenus à partir des données canadiennes.

Dans ce sens, nous étudions le cas d'une petite économie ouverte, pour capter la prime d'équité et voir si les résultats obtenus par les études précédentes[2] tiennent une fois que l'on instaure un marché d'échange international dans le modèle. En effet, l'introduction d'un marché d'échange avec l'étranger dans ce genre de modèle donne un nouveau canal au lissage de la consommation par les agents, on doit alors s'attendre à ce que la prime de risque baisse vu que la covariance entre le rendement de l'actif risqué et l'utilité marginale de la consommation diminue.

Ainsi, nous utilisons la méthode de linéarisation (King et al., 1988) en combinaison avec une formulation non linéaire des prix des actifs (Campbell, 1986 et 1996), ce qui va permettre à la fois de capter la différence entre les rendements ex-ante des titres financiers et par conséquent d'étudier le comportement de la prime de risque dans ce modèle.

En second plan, nous appliquons une formulation de prix lognormal suivant la méthode de Hansen et Singleton (1983), étudiée dans Jermann (1998). Cette technique permet de capter la prime de risque dans le cadre d'une économie ouverte, d'étudier les

[2]Voir Jermann, 1998, Benninga et Protopapadakis, 1990, Danthine et al., 1992, et Rouwenhorst, 1995, entre autres.

prédictions des modèles avec économie de production dans ce cadre et de se pencher sur le comportement de la consommation et des prix des actifs une fois qu'on introduit la possibilité d'avoir des créances sur l'étranger.

Dans un second essai, on s'intéresse à une autre dimension du problème des fluctuations macroéconomiques, à savoir l'effet des chocs financiers et monétaires sur l'activité économique réelle. À cet effet, nous examinons en profondeur l'impact des chocs de politique monétaire et des crises sur le marché boursier sur le volet réel de l'économie. Nous étudions d'abord l'exogèneité des deux perturbations, et analysons par la suite leurs implications sur les variables macroéconomiques.

Malgré le fait que les chocs aux politiques monétaires soient bien documentés dans la littérature [Romer et Romer (1989, 1994 et 2004), Leeper (1997), Christiano, Eichenbaum et Evans (1996), Barth et Ramey (2001) et Boivin (2001)], rien n'est encore fait pour la nouvelle mesure de Romer et Romer (2004), ni pour les crises survenues sur le marché boursier. Ainsi nous essayons de vérifier leur exogèneité et leur impact sur l'économie.

Notre objectif est d'étudier les effets des chocs monétaires et financiers sur diverses variables macroéconomiques. L'exactitude de cette évaluation dépend essentiellement des mesures de chocs utilisées. Ainsi, nous employons la nouvelle mesure des chocs de politique monétaire aux États-Unis développée récemment par Romer et Romer (2004), et les dates de chocs boursiers établies par Mishkin et White (2002), vu qu'elles donnent une bonne approximation des chocs qu'on veut étudier.

En outre, nous utilisons la procédure économétrique employée pour la première fois par Leeper (1997) pour étudier l'exogenéité des variables binaires de Romer et Romer (1989, 1994). Cette méthodologie combine l'approche narrative avec un vecteur autorégressif (VAR) afin de vérifier si ces chocs contiennent une composante endogène.

Comme il a été mentionné ci-dessus, notre mesure de choc monétaire, développée récemment par Romer et Romer (2004), est basée sur leurs lectures des rapports des rencontres de la commission fédérale des marchés financiers (FOMC), combinées avec l'information sur le taux de rendement de la réserve fédérale. Romer et Romer (2004) incorporent leur mesure de chocs à la politique monétaire dans un VAR suivant les travaux de Christiano, Eichenbaum et Evans (1996). Ils trouvent que les chocs de politique monétaire identifiés ont des effets statistiquement significatifs et qu'un choc négatif de politique monétaire produit une réponse forte de l'output et une réponse forte et négative du niveau des prix.

En ce qui concerne les crises financières, nous employons les dates identifiées par Mishkin et White (2002). Les auteurs appliquent une approche narrative dans le sens des travaux de Hamilton (1983) et de Romer et Romer (1989, 1994) pour identifier les dates où le marché boursier s'est effondré aux États-Unis au cours du siècle dernier.

Basé sur leur analyse historique de toutes les crises sur le marché financier au vingtième siècle aux États-Unis, Mishkin et White (2002) identifient les crises majeures ayant frappés le secteur financier. Leur définition du crash boursier suppose une forte perte soudaine de valeur des actions des sociétés cotées en bourse. En effet, en utilisant les indices boursiers (Dow Jones, S & P 500 et le NASDAQ), la taille de l'effondrement, la durée de la crise comme moyen d'identification et les crashs universellement reconnus d'octobre 1929 et 1987 comme repères, ils identifient 15 crises financières principales pendant le dernier siècle. Ainsi, à partir de ces dates, nous construisons une variable binaire qui prend la valeur un aux dates identifiées par Mishkin et White, et zéro ailleurs.

Nos résultats montrent, selon toute évidence empirique, que les deux types de chocs (crise financière et chocs au politique monétaire) sont exogènes. Ces résultats restent valides même lorsque nous incluons d'autres chocs exogènes dans le VAR ou quand différents poids sont attribués aux dates de crise financière. On démontre aussi que ces perturbations ont des effets significatifs sur l'activité économique réelle.

Le troisième essai traite en profondeur la réaction de la banque centrale face à des fluctuations au niveau de l'inflation et du niveau des prix. On s'intéresse en particulier à la cible d'inflation et au niveau de prix dans un modèle hybride de type 'néo-Keynésien' comme objectif de la banque centrale dans le cas d'une petite économie ouverte.

La cible d'inflation a été largement adoptée dans la conduite de politique monétaire visant à stabiliser les prix tout au long de la dernière décennie. En effet, plusieurs pays industrialisés, dont le Canada, ont adopté des règles ciblant un taux préétabli d'inflation et jusqu'ici, la plupart d'entre eux semblent enregistrer de bonnes performances tant en matière d'inflation que de croissance économique.

En revanche, plusieurs auteurs démontrent que la cible de niveau de prix induit une inflation à court terme plus élevée et une grande variabilité de l'output que celles enregistrées avec la cible du taux d'inflation (CI) (voir Fischer, 1994, Haldane et Salmon, 1995). Cependant, Dittmar et al. (1999) et Svensson (1999) avancent des arguments en faveur de la cible du niveau des prix (CP) suggérant que la variabilité d'inflation devienne inférieure avec la CP, si on suppose qu'on a une persistance modérée de l'output. Dans la pratique, le seul pays à avoir adopté la CP était la Suède dans les années 30 (voir Berg et le Jonung, 1999).

Notre but ici est d'approfondir la recherche sur le modèle hybride en supposant la présence dans l'économie d'une banque centrale ciblant en même temps le taux d'inflation et le niveau des prix. Le cadre d'analyse adopté est celui d'une petite économie ouverte avec un modèle néo-Keynésien. L'avantage d'un tel environnement réside dans le comportement 'forward-looking' des agents représentatifs, ce qui conduit par exemple à la stabilisation du problème de biais, une fois que l'autorité monétaire adopte une politique monétaire discrétionnaire (Clarida et al., 1999).

Dans ce travail, nous proposons d'étudier le comportement du régime hybride tout en le différenciant de deux autres types de politique monétaire, à savoir un régime ciblant uniquement le taux d'inflation et un autre ciblant plutôt le niveau des prix. Nous nous pencherons ici sur plusieurs questions que pose la conduite de la politique monétaire dans un tel cadre. Plus précisément, nous comparons différentes règles suivies par des autorités monétaires déterminées à assurer la stabilité des prix, ainsi que les répercussions de ces règles sur les propriétés dynamiques des agrégats économiques.

L'adoption de la version de petite économie ouverte implique que des variables étrangères peuvent être incluses dans chaque équation du modèle, ce qui génère plus de dynamique dans ce genre de modèle. Ces différences peuvent influencer les résultats déjà obtenus dans la littérature pour le régime hybride. Notre étude se démarque de la littérature existante[3] du fait qu'on adopte un cadre d'analyse néo-Keynésien auquel on applique une analyse de bien-être économique. Avec ses fondements microéconomiques ce cadre d'analyse a l'avantage de s'approcher plus de la réalité économique et donc à donner des résultats intéressantes quand à l'étude des politiques monétaires et à la comparaison entre différentes règles de conduite de cette politique.

Après avoir calibré le modèle sur l'économie canadienne et analysé les différentes réponses aux chocs frappant l'économie, on évalue les différents régimes en se basant sur la perte du bien-être de chaque régime. Les résultats obtenus montrent que le modèle hybride peut, s'il est adopté, fournir une bonne alternative aux régimes ciblant uniquement le taux d'inflation ou le niveau des prix, la perte de bien-être de l'agent économique étant négligeable.

[3]Parmi ces études on peut citer Batini et Yates (2003) et Kobayashi (2004) qui ont analysé le régime hybride dans des cadres d'analyses différents de celui qu'on adopte dans ce travail.

CHAPITRE I

EQUITY PREMIUMS IN A SMALL OPEN ECONOMY

1.1 Introduction

In recent years the frontiers between financial economics and macroeconomics have steadily narrowed. Indeed, many empirical studies focus on the behavior of asset prices in relation to consumption and other business cycle variables. General equilibrium models have been successful in explaining the dynamics of macroeconomic aggregates, but have failed to replicate similar interesting stylized facts when studying the behavior of asset prices. Empirically, financial economic studies have documented important cyclical variations in security returns and risk premia.

To some extent, during the last two decades the principal question in most business cycle studies has been to reconcile data and economic theory, and therefore construct models with endogenous processes able to generate the fluctuations observed in the data. In fact, the data (taken from postwar quarterly data for the industrialized countries) shows for example that consumption is smooth and that the covariance between quarterly real consumption growth and real dividend growth is very weak. Nevertheless, the study of the equity premium can be seen as a prime example of where these models fall apart.

In fact, among the abundant literature treating the relation between economic fluctuations and asset prices, the endowment model of Lucas (1978) was the first to be established as a baseline. A financial asset model based on consumption was later introduced by Hansen and Singleton (1983). In this kind of model the quantity of risk in the financial market is measured by the covariance of the excess stock return with consumption growth, while the risk price is the coefficient of the representative agent's relative risk aversion. Based on the data[1] however the average stock return is very high and the riskless interest rate is low. This means there is high expected excess return on stock (the equity premium), while on the other hand the data reveals low covariance between stock returns and consumption. In this case only a very high coefficient of risk aversion can explain the high equity premium, which Mehra and Prescott (1985) have called the 'equity premium puzzle'.[2]

Our purpose here is to introduce a foreign sector to the model studied by Jermann (1998),[3] and in this way permit the representative household to have access to financial credits on the foreign economy. Incorporating the foreign sector will thus provide another opportunity for agents to smooth their consumptions. With this in mind we study the model's business cycle and asset pricing implications, enabling us to determine whether the results obtained by preceding studies[4] will hold once the foreign economy is introduced. This essentially allows us to study equity premium behavior, in the case of a small open economy, with habit persistence in preferences and adjustment costs of capital, the case we intend to assess here.

Kandel and Stambaugh (1991), in response to the equity premium puzzle, argue that risk aversion is much higher than what has been traditionally thought. But, if agents are very risk averse, they have a strong desire to transfer wealth from a 'good' period (with high consumption) to a 'bad' period. Since consumption grows steadily over time,

[1] For a survey of the stylized facts related to the consumption-asset pricing framework, see Campbell (2001).

[2] See also Cochrane and Hansen (1992) and Kocherlakota (1996) for more details on this puzzle. A brief summary of the other enigmas found in literature concerns : 'the riskfree rate puzzle' in Weil (1989), 'the stock market volatility puzzle' in LeRoy and Porter (1981) and Shiller (1981); to quote only the most documented.

[3] The one sector version of the RBC model with adjustment cost of capital and fixed labor.

[4] These include Jermann (1998), Benninga and Protopapadakis (1990), Danthine et al. (1992) and Rouwenhorst (1995).

the high risk aversion makes agents want to borrow in order to reduce the discrepancy between present and future consumption. Campbell (2001) shows that to reconcile this with the low observed real interest rate, we must postulate that agents are very patient ; thus they have a low or even negative rate of time preference. Weil (1989) calls this the 'risk-free rate puzzle'.

Several studies tried to resolve those enigmas. One method was to introduce a class of utility functions and payout structures that could generate large variability for consumption's marginal utility. A model with a representative agent whose utility displays habit formation, introduced by Sundaresan (1989) and Constantinides (1990) produces this variability and can, in this way, resolve the puzzling equity premia problem.

The idea behind the relative success of this utility function (as shown recently by Campbell and Cochrane, 1999), is that specifications for habit formation make agents more risk averse in bad times than in good times, when consumption is high compared to its past history. Thus the equity premium can be explained by the high volatility of market stocks together with a reasonable degree of average level of risk aversion.

Nevertheless, Rouwenhorst (1995) explains that in a closed economy, consumption smoothing must arise through capital accumulation. Thus, it is difficult to explain substantial risk premia because agents smooth their consumption when risk aversion increases. The introduction of capital adjustment costs may however solve this problem and with appropriate specifications for the utility function, equity premiums with several percentage points can be generated (Jermann, 1994). Indeed an extended version of the RBC model including consumption habits may provide a key channel within which risk premiums may be generated, because the agents in this model become more risk averse. Consumption smoothness is desired here but when combined with capital adjustment costs, stock return becomes risky and large equity premiums may result (as shown by Budría, 2002).

Constantinides (1990) demonstrates that in models with trivial production sectors, habit persistence in preferences may potentially account for both risk-free and equity premium asset price puzzles, while implying only a modest level of household risk aversion. In addition to habit formation,[5] another ingredient needed to successfully obtain equity premia consists of those technology features that prevent households from smoothing their consumption. Jermann (1998) shows that capital adjustment costs play a crucial role in this way. The model thus specified will not only explain the puzzling asset prices but also match a set of salient macroeconomic statistics.

Boldrin et al. (2001) introduce two modifications into the standard real business cycle model : habit persistence preferences and limitations on factor mobility between the two sectors[6] of the economy. The second assumption concerns the fact that the sectorial and aggregate allocations of capital and labor are determined before the achievement of uncertainty in the current period. The resulting model is consistent with observed mean equity premiums and mean risk free rates.

We follow Jermann (1998) through combining the loglinear reduced form along the lines of King, Plosser and Rebelo (1988) and the asset pricing formulae based on the lognormality of the distribution introduced by Hansen and Singleton (1983), and more recently by Campbell (1986 and 1996). The framework presented here extends that of Jermann (1998) by introducing a foreign sector into the model and a 'risk premium' term to remove the model's built-in random walk property as shown below. A standard feature of most current open economy models is a relation implying uncovered interest parity (UIP), despite its prominent empirical weaknesses as shown by McCallum and Nelson (2000).

Our results show that this model is not able to explain equity premium. Indeed the model generates small equity premiums when compared to that observed in the historical data. This failure can be attributable to the fact that, with access to international financial markets, domestic households may again play on the smoothing of their consumption. In this case the substantial addition brought to the standard RBC

[5]Given its success in solving the puzzling equity premia in models including production. See Abel (1990) and Constantinides (1990).

[6]Boldrin et al. (1999) assume that consumption and investment are non-homogeneous goods produced in separate sectors.

model by habit formation and capital adjustment costs would be canceled by the opening of the economy to international financial markets. Additionally, domestic agents may reduce fluctuations in consumption by borrowing (or lending) from foreigners in bad (or good) periods. Nevertheless our model is able to match business cycle statistics, and compared to the standard RBC model it is better able to explain equity premia in several basis points.

This chapter is structured as follows. Section 1.2 presents the model setting and discusses its solution, Section 1.3 examines the model predictions and presents the results, and Section 1.4 contains concluding remarks.

1.2 The model

1.2.1 Model Setting

We consider the case of a small open economy[7] with a continuum of identical infinitely lived households. The representative agent in both countries (the home country and the rest of the world) maximizes the expected discounted sum of utility. There is a single consumption/investment good in the world, produced by domestic and foreign firms according to constant-returns-to-scale production technology, such that import and local production are perfect substitutes. Each firm finances its investment through retained earnings.

Firms

We assume that the representative domestic firm, which is owned by domestic households, has two types of purchasers, who are domestic and foreign customers to whom it may sell its goods. In each period the firm has to decide how much labor to hire and how much to invest. The manager's problem is to maximize the value of the firm to its

[7]The model is a modification of the one-sector, fixed labor model.

owners[8]

$$E_t \sum_{j=0}^{\infty} \beta^j \frac{\Lambda_{t+j}}{\Lambda_t}\{Y_{t+j} - W_{t+j}n_{t+j} - I_{t+j}\}$$

subject to the constraint given below

$$Y_t = Z_t K_t^{\alpha} {n_t}^{1-\alpha}, \quad 0 < \alpha < 1 \tag{1.1}$$

where $\beta^j \Lambda_{t+j}/\Lambda_t$ is the marginal rate of substitution of the household and n_t the quantity of labor input. The state of technology evolves according to the AR(1) process

$$Z_t = \rho_z Z_{t-1} + \epsilon_{zt}, \tag{1.2}$$

where ϵ_{zt} is a normally distributed white noise with mean 0 and variance σ^2 for all $t \geqslant 0$.

Prior research – in the case of closed economy – has found that endogenous consumption becomes even smoother as risk aversion is increased. In this way, it is more difficult to explain substantial risk premia (Rouwenhorst, 1995). The intuition behind this is that agents can easily alter their production plans to smooth their consumption. Thus, with this frictionless and instantaneous capital stock adjustment, this problem cannot be solved. Jermann (1994) suggests the introduction of capital adjustment costs in order to overcome this weakness. The specification of the function follows Jermann (1998), that is,

$$\phi(\frac{I_t}{K_t}) = \frac{a_1}{1-(1/\xi)}(\frac{I_t}{K_t})^{1-(1/\xi)} + a_2$$

where $\phi(.)$ is a positive, concave function.[9] Thus, the resources allocated to investment are not transformed into the next period capital with a rate equal to one. The parameter ξ is the elasticity of investment, I_t, with respect to Tobin's q , and a_1, a_2 are chosen so

[8]The value of the firm is equal to the present discount value of all current and future expected cash flows (as shown by Jermann, 1998). Here for the financing path we use the Modigliani-Miller theorem.

[9]The concavity of the cost function captures the idea that changing capital stock rapidly costs more than changing it slowly (see Eisner and Strotz ,1963 and Lucas and Prescott, 1971).

as to yield a balanced growth path, for those variables in the model that are invariant to ξ (see Boldrin et al., 2001 for more details).[10] The value of ξ strongly affects the concavity of the adjustment cost function. Indeed as shown in Figure 1.1,[11] the function $\phi(.)$ is more concave when ξ is low.

The technology for accumulating capital is as follows

$$K_{t+1} = (1-\delta)K_t + \phi(\frac{I_t}{K_t})K_t, \quad 0 < \delta < 1. \tag{1.3}$$

where δ is the depreciation rate of capital.

There are no new shares issued by the firm and the capital stock is financed through retained earning (RE), defined as

$$I_t = RE_t.$$

The domestic household has access to incomplete international financial markets, because the only foreign asset they can hold is a risk-free bond whose rate of return is exogenously determined. In this case the initial conditions, in particular the home country's initial foreign debt position, govern the model's steady state values. As a consequence, a random walk[12] component can prevent the model's dynamic equilibrium from reaching a stable solution. To induce stationarity and remove the model's built-in random walk property, we use an endogenous country-specific risk premium term κ_t, that reflects departures from uncovered interest parity (UIP).[13] Following Senhadji (1995), Mendoza and Uribe (2000), Schmitt-Grohe and Uribe (2003), and Dib (2003), this risk premium term is given by

[10] Here as in Boldrin et al. (2001), we set a_1 and a_2 to :
$$a_1 = (\exp(\bar{x}) - 1 + \delta)^{(1/\xi)}, \quad a_2 = \frac{(1/\xi)}{1-(1/\xi)}(1 - \delta - \exp(\bar{x})).$$

[11] The figure is taken from Budría, (2002) who uses the same calibration and functional form that we use.

[12] At least one eigenvalue in the model is equal to unity.

[13] That is, the equilibrium steady state is unique and the model is stationary (see Dib 2003).

$$\kappa_t = \exp(-\frac{\varphi \tilde{B}_t^*}{Y_t}), \tag{1.4}$$

where $\tilde{B}_t^*$ is the average of aggregate foreign debt and φ measures the level of risk premium. The term risk premium implies that the equilibrium is unique and induces stationarity in the model. At equilibrium the market clearing condition yields

$$\tilde{B}_t^* = B_t^* \text{ for all } t.$$

There are three assets in this economy that are traded in incomplete financial markets. Household can then purchase a perfectly divisible equity share of the representative domestic firm that is a claim to an infinite stream of the firm's dividends (A_t); so at time t, this asset delivers a payout (dividends) denoted by D_t. This asset can be purchased only by domestic households[14] who must pay P_t^s to obtain it. They can also purchase two types of one-period riskless bonds (domestic and foreign bond). At the end of period t, the firm's dividends to shareholders satisfy the following equation

$$D_t = Y_t - I_t - W_t n_t.$$

Households

The representative agent derives utility from consumption of a final good C_t. The preferences exhibit a simple form of habit formation, that is a stock of past consumption X_t that affects current utility

$$E_t \sum_{j=0}^{\infty} \beta^j [\frac{(C_{t+j} - X_{t+j})^{1-\gamma}}{1-\gamma}], \qquad 0 < \beta < 1 \tag{1.5}$$

[14]It is assumed here that foreigners purchase only those bonds denominated in their own output.

where γ is a positive parameters[15] different from 1. The habit stock X_t evolves as follows

$$X_t = bC_{t-1} \tag{1.6}$$

wherein we define the case where $b > 0$ as the habit persistence preferences case. When $b = 0$, these preferences correspond to those in a standard RBC model with fixed labor.[16]

In the case of habit persistence in the utility function, the representative agent is concerned with maintaining the same level of consumption period by period. As shown by Constantinides (1990) and Lettau and Uhlig (1997), the coefficient of relative risk aversion, γ must not be high, because in this case relative risk aversion becomes more sensible. To show this we can compute elasticity of intertemporal substitution (ES) and relative risk aversion (RRA). Following Lettau and Uhlig (1997) and Allais et al. (2000), and assuming that the logarithm of consumption follows a random walk with drift yields

$$C_{t+1} = g + C_t + \varepsilon_{t+1}.$$

The inverse of ES is given by[17]

$$\frac{1}{ES} = \left(\frac{\gamma}{1 - b\exp(-g)}\right)\left(\frac{1 + \beta b^2 \exp(-(\gamma+1)g)}{1 - \beta b \exp(-\gamma g)}\right)$$

and the RRA follows

$$RRA = \frac{\gamma}{1 - b\exp(-g)\frac{\exp(-\gamma g) - \beta\gamma}{\exp(-\gamma g) - b\gamma}}.$$

Evidently, with no habit persistence ($b = 0$) the inverse of ES is simply γ. Moreover, relative risk aversion is strongly related to the habit parameter.[18].

[15]In the special case where $\gamma \rightarrow 1$, the logarithmic function is obtained.

[16]The term bC_{t-1} can be seen as the household's habit stock, thus, b cannot be negative.

[17]See Lettau and Uhlig (1997) for more details.

[18]Allais et al. (2000) compute the RRA and ES for Canada and argue that the presence of habit forming in preferences is likely to reach the value found in the data, and the model similar to what we present here can better account for price changes for financial assets.

In its portfolio the household has a domestic firm share and can also purchase one type of one period riskless bond B_t (domestic risk-free bond[19]) denominated in consumption units for P_t^f. It may also make a period t acquisition of one bond B_t^*, denominated on foreign output redeemed for one unit of foreign output one period later. The price[20] the household must pay for this bond is $\kappa_t{}^{-1}P_t^{e*-1}$. Thus, the price households must pay increases the ratio of foreign-debt to output, where the rate of return on A_t is conditional to date $t+1$ state of nature achievement while those on B_t and B_t^* are not. The two riskless bonds pay one unit of the consumption good (for each) at time $t+1$ and expire.[21]

Let $O_t = [B_t, A_t, B_t^*]$ be the asset vector that contains the domestic firm shares and assets described above. Likewise, let V_t^o and D_t^o denote the asset price vectors and current period payouts respectively.

The budget constraint is then given by the following inequality

$$O_{t+1}V_t^o + C_t \leqslant W_t n_t + O_t(V_t^o + D_t^o) \tag{1.7}$$

where W_t is the wage rate.

Since the representative firm does not issue new shares at date t, the household takes $A_{t-1}, B_{t-1}, B_{t-1}^*, X_{t-1}$ as given and maximizes

$$\underset{\{A_j,B_j,B_j^*,C_j,j\geqslant t\}}{Max} \quad E_t \sum_{j=0}^{\infty} \beta^j [\frac{(C_{t+j} - X_{t+j})^{1-\gamma}}{1-\gamma}]$$

subject to the habit persistence constraint $X_t = bC$, the budget constraint in (1.7) and the technology function (1.1).

The gross domestic product Y_t can either be used for consumption or investment

[19] As in Jermann (1998), we suppose that the possibility of bankruptcy is excluded, so that the corporate and riskfree bonds are perfect substitutes.

[20] McCallum and Nelson (1998) suppose a random "risk-premium" term that reflects temporary but persistent departures from uncovered interest parity, while here instead we assume an endogenous premium term to induce stationarity into our small open economy model.

[21] Domestic riskless bonds are assumed to be in aggregate zero supply.

and to pay foreign debt, or be considered as surplus (see appendix A for details).

General Equilibrium Model Solution

General equilibrium model solutions usually involve the application of the linearization method developed by King, Plosser and Rebelo (1988). This method implies that expected returns are equal across securities, so that risk premiums cannot be study. Danthine et al. (1992) show that the use of a solution technique with nonlinear functions can yield interesting results.

Following Jermann (1994), we use a combination of the loglinear and lognormal environments.[22] The solution in this case is to solve for the model's approximate dynamics represented by a loglinear state space system of the form $s_t = Ms_{t-1} + \epsilon_t$, where M is the square matrix that governs the system's dynamics. This step involves loglinearizing the first order conditions and solving the dynamic system.

The second step involves the lognormal pricing formula used by Hansen and Singleton (1983) and Campbell (1993). In this formula, the random future payout of dividends can be evaluated by the present value relationship (see Jermann 1994 for more details)

$$V_t[D_{t+k}] = \frac{\beta^k E_t[\Lambda_{t+k} D_{t+k}]}{\Lambda_t}$$

where Λ_t is the marginal numeraire valuation at period t. Furthermore, the relations between the dividend payout and the marginal valuation on the one hand and the state vector on the other hand, pass through the factors l_d and l_λ as follows

$$\begin{aligned} \lambda_t &= l_\lambda s_t \\ d_t &= l_d s_t, \end{aligned} \tag{1.8}$$

where the error terms are assumed to follow a multivariate normal *iid* process.

[22] As in Jermann (1994), we assume that the system's variables are stationary.

1.2.2 Numeraire Valuation

In our model the valuation (or marginal utility h_t,) is computed as follows

$$h_t = \frac{\partial U_t}{\partial C_t} = (C_t - bC_{t-1})^{-\gamma} - \beta b E_t (C_{t+1} - bC_t)^{-\gamma}. \tag{1.9}$$

Then through loglinearizing (1.9) and taking its first order Taylor series approximation around the steady state of consumption (c), it can be shown that

$$\begin{aligned} h_t &= \log[((1-b)c)^{-\gamma}(1-\beta b)] - \frac{\gamma(1+\beta b^2)}{(1-b)(1-\beta b)}(\frac{C_t - c}{c}) + \\ &\quad \frac{\gamma b}{(1-b)(1-\beta b)}(\frac{C_{t-1}-c}{c}) + \frac{\gamma \beta b}{(1-b)(1-\beta b)}(\frac{C_{t+1}-c}{c}). \end{aligned} \tag{1.10}$$

Next, we approximate $\frac{C_t - c}{c}$ as the difference between log of time t consumption and the log of steady state consumption, i.e.

$$\frac{C_t - c}{c} \simeq \log(C_t) - \log(c),$$

to finally compute the following expression for h_t

$$\begin{aligned} h_t &= \log[((1-b)c)^{-\gamma}(1-\beta b)] + \frac{\gamma[b(\beta - b\beta - 1) - 1]}{(1-b)(1-\beta b)}\log(c) \\ &\quad - \frac{\gamma(1+\beta b^2)}{(1-b)(1-\beta b)}c_t + \frac{\gamma b}{(1-b)(1-\beta b)}c_{t-1} + \frac{\gamma \beta b}{(1-b)(1-\beta b)}c_{t+1}. \end{aligned} \tag{1.11}$$

where c_t stands for the log of the time t consumption expenditure.

In this formula we can ignore the constant term when evaluating the relation between consumption expenditure and realized marginal utility h_t, and marginal valuation Λ_t . Thus, we can approximate the marginal utility locally by

$$h_t = \frac{\gamma \beta b}{(1-b)(1-\beta b)}c_{t+1} - \frac{\gamma(1+\beta b^2)}{(1-b)(1-\beta b)}c_t + \frac{\gamma b}{(1-b)(1-\beta b)}c_{t-1}.$$

Now we turn to the risk premium issue.

1.2.3 Risk Premium Computation

We let $H_{t,t+s}$ be lifetime marginal utility and then we assume the following relation between its log, $(h_{t,t+s})$ and a distributed lead of the state vector's log[23]

$$h_{t,t+s} = \sum_{j=0}^{s} l_h(j) s_{t+j}. \tag{1.12}$$

Therefore, we can evaluate time t expectations over the lifetime marginal utility within the framework of asset pricing case as follows

$$E_t(H_{t,t+s}) = E_t \exp(h_{t,t+s}).$$

Assuming that $H_{t,t+s}$ is normally distributed, lognormality implies that the right hand side (RHS) of the above equation can be rewitten as

$$E_t(H_{t,t+s}) = \exp(E_t h_{t,t+s}) + \frac{1}{2} var_t(h_{t,t+s}).$$

Consequently, the value of a claim to a potentially random future payout D_{t+k} reduces to

$$V_t(D_{t+k}) = \frac{\beta^k E_t(\exp(h_{t+k,t+s+k}) D_{t+k})}{E_t \exp(h_{t,t+s})}. \tag{1.13}$$

Using the law of iterative expectations, the numerator of (1.13) can be rewritten as

$$E_t[E_{t+k}(\exp(h_{t+k,t+s+k})) D_{t+k}].$$

Given that D_{t+k} is deterministic at t+k, and under the lognormality assumption,

[23]In what follow we use the presentation of Jermann (1994).

the previous expression becomes

$$E_t[\exp(E_{t+k}(h_{t+k,t+s+k}) + \frac{1}{2}var_{t+k}(h_{t+k,t+s+k}))D_{t+k}].$$

Furthermore, with the variance term which does not depend on the state of the system, (1.13) then reduces to

$$V_t(D_{t+k}) = \frac{\beta^k E_t(\exp(E_{t+k}(h_{t+k,t+s+k}) + \frac{1}{2}var_{t+k}(h_{t+k,t+s+k}))D_{t+k})}{\exp(E_t h_{t,t+s} + \frac{1}{2}var_t(h_{t,t+s}))}.$$

Moreover, as the two variance terms cancel out, it follows that

$$V_t(D_{t+k}) = \frac{\beta^k E_t(\exp(E_{t+k}(h_{t+k,t+s+k}))D_{t+k})}{\exp(E_t h_{t,t+s})}, \tag{1.14}$$

so that $\Lambda_t = \exp(E_t h_{t,t+s})$ can be used as the marginal numeraire valuation.

Expected Return

Following Jermann (1998), we focus on single-payout assets in order to define a one-period holding return as

$$R_{t,t+1}(D_{t+k}) = \frac{V_{t+1}(D_{t+k})}{V_t(D_{t+k})}. \tag{1.15}$$

Hence, we first have to evaluate the period t expected value of $V_{t+1}(D_{t+k})$. The lognormality assumption therefore implies that

$$\begin{aligned} E_t[V_{t+1}(D_{t+k})] &= \beta^{k-1} E_t \exp[(E_{t+1}(d_{t+k} + h_{t+k} - h_{t+1}) + \frac{1}{2}var_{t+1}(d_{t+k} + h_{t+k})] \\ &= \beta^{k-1} \exp[E_t(d_{t+k} + h_{t+k} - h_{t+1}) + \frac{1}{2}var_t(E_{t+1}(d_{t+k} + h_{t+k} - h_{t+1})) \\ &\quad + \frac{1}{2}var_{t+1}(d_{t+k} + h_{t+k})]. \end{aligned}$$

The conditional expectation on the holding return can then be calculated as follows

$$E_t[R_{t,t+1}(D_{t+k})] = E_t\{\exp[\frac{1}{2}var_{t+1}(d_{t+k}+h_{t+k})] \frac{\beta^{k-1}\exp[E_t(d_{t+k}+h_{t+k}-h_{t+1})+\frac{1}{2}var_t(E_{t+1}(d_{t+k}+h_{t+k}-h_{t+1}))]}{\beta^k\exp[E_t(h_{t+k}+d_{t+k}-h_t)+\frac{1}{2}var_t(d_{t+k}+h_{t+k})]}\}.$$

As we assumed early on, the variance term is state-independent so that

$$E_t[R_{t,t+1}(D_{t+k})] = E_t\beta^{-1}\frac{\exp[E_t(d_{t+k}+h_{t+k}-h_{t+1})+\frac{1}{2}var_t(E_{t+1}(d_{t+k}+h_{t+k}-h_{t+1}))\ ]}{\exp[E_t(h_{t+k}+d_{t+k}-h_t)\ ]}.$$

As a result,

$$E_t[R_{t,t+1}(D_{t+k})] = E_t\beta^{-1}\exp[E_t(h_t-h_{t+1})+\frac{1}{2}var_t(E_{t+1}(d_{t+k}+h_{t+k}-h_{t+1}))]\ ,$$

which can be shown to reduce to

$$E_t[R_{t,t+1}(D_{t+k})] = R_{t,t+1}(1_{t+1})\exp[\frac{1}{2}var_t(E_{t+1}(d_{t+k}+h_{t+k}-h_{t+1}))]\ ,$$

or, alternatively,

$$E_t[R_{t,t+1}(D_{t+k})] = R_{t,t+1}(1_{t+1})\exp[-cov_t(h_{t+1},E_{t+1}(h_{t+k}-h_{t+1}))-cov_t(h_{t+1},E_{t+1}(d_{t+k}))] \tag{1.16}$$

which is the conditional expected return.

As shown by Jermann (1994), even though the RHS of this equation can be divided into three components,[24] we are only interested in the first term which represents the

[24] See Jermann (1998) for more details on this specification. The three components are : riskfree rate, the term uncertainty premium which represents the term premium for a k-period discount bond and the last element, which is the payout uncertainty premium.

risk-free rate

$$
\begin{aligned}
R_{t,t+1}[1_{t+1}] &= 1/V_t[1_{t+1}] \\
&= \beta^{-1}\exp(h_t - E_t h_{t+1} - \frac{1}{2}var_t(h_{t+1})).
\end{aligned}
\tag{1.17}
$$

In order to quantify the equity premium, we need to obtain the risk-free rate's conditional expectation. To do so let us first compute the conditional variance.

Conditional Variance

With the lognormality assumption it is possible and useful to compute the conditional variance of asset returns. As by definition[25]

$$
R_{t,t+1}[D_{t+k}] = E_t(R_{t,t+1}[D_{t+k}])\frac{V_{t+1}[D_{t+k}]}{E_t(V_{t+1}[D_{t+k}])}, \tag{1.18}
$$

and focusing on the RHS, it can be shown that

$$
\begin{aligned}
\frac{V_{t+1}[D_{t+k}]}{E_t(V_{t+1}[D_{t+k}])} &= \exp(E_{t+1}(d_{t+k} + h_{t+k} - h_{t+1}) - E_t(d_{t+k} + h_{t+k} - h_{t+1}) \\
&\quad -\frac{1}{2}var_t(E_{t+1}d_{t+k} + h_{t+k} - h_{t+1})).
\end{aligned}
$$

As a result,

$$
var_t(R_{t,t+1}[D_{t+k}]) = E_t(R_{t,t+1}[D_{t+k}])^2(\exp(E_{t+1}(d_{t+k} + h_{t+k} - h_{t+1}))) \tag{1.19}
$$

which represents the conditional variance of asset returns.

[25] Here we use the fact that : $\frac{1}{V_t[D_{t+k}]} = \frac{E_t(R_{t,t+1}[D_{t+k}])}{E_t(V_{t+1}[D_{t+k}])}$.

1.3 Model Predictions

1.3.1 Market Equilibrium

The market-clearing condition for the goods market requires that all produced final goods be consumed, invested or used in order to pay capital adjustment costs and period asset returns. If we normalize the number of households and firms to one, then the resource constraint holds in an equal manner, and also labor demand equals labor supply. Financial market equilibrium occurs when agents hold all outstanding shares and corporate bonds[26] and all other assets are in zero supply. The sequence of markets equilibrium is defined as usual.

1.3.2 Model Calibration

The values assigned to model parameters are those estimated by Letendre (2003) for the Canadian economy. Certain other values have been chosen from the literature so that the model can reproduce some small open economy features. We consider parameters within the range of values generally considered as being linked to the habit formation (HF) case. Indeed the preference parameter γ is set to 2. As discussed in Jermann (1998) and Budría (2002), in the case of HF preferences this parameter is close to risk aversion. Campbell (1993) estimates this value to be between 5 and 8, but mean reversion in asset prices may increase this value by up to three times (Black, 1990). Boldrin et al. (1995) assume a value of 1 for the HF case. The depreciation rate is set to 0.025, the subjective discount factor is set to 0.96, and the steady state value of n to 0.33. Also the steady state risk premium parameter φ is set to 0.0054, which implies an average risk premium of 98 basis points at an annual rate (as in Clinton, 1998, reporting estimates for Canada). The capital share in production is set to 0.32, the parameter of habit persistence b to 0.58. Cochrane and Hansen (1992) use 0.5 and 0.6 for this parameter, while Constantinides (1990) requires a level of 0.8.

[26]The domestic corporate bonds are detained by domestic agents.

The elasticity of investment with respect to Tobin q is estimated in the literature to have values ranging from 0.4 to 1.14. Abel (1980) estimates this parameter to be between 0.27 and 0.52, and Jermann (1998) sets ξ equal to 0.23, which is the high adjustment cost case. We adopt this parametrization and set ξ to 0.23. Finally the productivity shock parameter is set to 0.94436[27] as estimated by Letendre (2003) for Canada, with a standard deviation of 0.00599. See Table 1.1 for a summary of these values.

1.3.3 Model Solution

As shown by Boldrin et al. (1999) and Jermann (1988), in the RBC model the equity premium is low. Intuitively, this result is due to the fact that in RBC models the Sharpe ratio for equity (SR) and the standard deviation for real return to equity, σ_{r^e}, are low. Hence, for a production economy defining the equity premium as $E(r^e_{t+1} - r^f_t) = SR.\sigma_{r^e}$ naturally leads to a low value for the premium. Indeed, the equity premium remains at zero and the result is invariant to the introduction of habit persistence in the utility function.[28] As discussed before the introduction of adjustment cost of capital in a model with habit preferences and fixed worked hours increases σ_{r^e} to a large value and this yields a substantial equity premium.

In the case of the lognormal pricing model, we assume that the dividend (D_t) and the marginal valuation (Λ_t) are lognormal. The joint distribution is given by the vector process for state variables. In this case, the equity premium as defined is usually computed as the difference between the unconditional mean equity return and the unconditional mean risk-free rate, thus we need to apply the lognormal pricing formulae to the two rates (on the equity and risk-free rates), whereas the one period holding return is defined as

$$R^e_{t,t+1} = \frac{V_{t+1}(D_{t+k})}{V_t(D_{t+k})}$$

[27]See Prescott (1986) for a discussion of Solow residual estimates.

[28]In our model the change in b let the equity with no significant change.

for k period asset holding . In the risk-free rate case the expression becomes

$$R^f_{t,t+1} = \frac{1}{V_t(1_{t+k})}.$$

Following Jermann (1998), the risk-free rate can thus be rewritten as

$$R^f_{t,t+1} = \beta^{-1} \exp[\lambda_t - E_t\lambda_{t+1} - \frac{1}{2} var_t(\lambda_{t+1})] \tag{1.20}$$

where λ_t is the logarithm of the valuation, Λ_t. The unconditional expectation corresponding to (1.20) is then given by

$$E(R^f_{t,t+1}) = \beta^{-1} \exp[\frac{1}{2}(var(E_t\lambda_{t+1} - \lambda_t) - var(\lambda_{t+1} - E_t\lambda_{t+1}))],$$

which is trivially computed from the model solution. However, although return to the firm's equity can be written as

$$R^e_{t,t+1} = \frac{V^D_{t+1} + D_{t+1}}{V^D_t},$$

it is still difficult to get an analytical closed form solution for the unconditional expectation of this return. As shown by Jermann (1998) we can overcome this shortcoming by applying numerical simulation.

1.3.4 Summary of Numerical Results

The models' predictions for mean returns and business cycle statistics are shown in Tables 1.2 and 1.3. The results obtained show that the equity premium computed using the lognormal formulae is about 0.025% (2.5 basis points annually), which is extremely low when compared to the premium obtained using historical data. For example Allais et al. (2000) report an equity premium of 3.47% for Canada. See Table 1.2 for a summary of results, with Canadian data used for comparison purposes.

This means that even with habit persistence in preferences and capital adjustment costs, the model fails to account for a substantial equity premia when a foreign sector is introduced. This failure can be explained by the smoothing of household consumption when confronted with fluctuations in their consumption plans. In this case they can borrow from or lend to a foreign country to obtain the same level of consumption. As explained before with habit persistence, economic agents are not only concerned by the actual level of consumption, but they are also intended to maintain the same consumption level period by period.

Despite this failure, the model is able to provide high equity premiums compared to those obtained by the standard RBC model (which gives no equity), and is also able to match selected business cycle statistics. For example, the standard deviation of output is 1.78, compared to about 1.72 for the Canadian data. The relative deviation between consumption and output is about 0.179 while the data gives 0.54, which can be explained by the model's smoothness of consumption. In fact, consumption's standard deviation at 0.32 is three times less volatile compared to the value of 0.93 obtained in the data[29]. These results show that the RBC model augmented with habit formation and adjustment costs fails to account for asset pricing statistics when a new element, the foreign sector, is introduced into the model. As discussed in Abel (1991), interest rate volatility is too high, representing a problem with habit persistence in that it makes this rate too volatile. Likewise, habit formation preferences display a strong aversion to intertemporal substitution which in turn leads to high variations in interest rates (Jermann, 1998). Furthermore, the model overpredicts riskless rate volatility in part because a high value of the parameter that governs habit persistence is needed to generate a sizeable equity premium. In models of this class, if one is willing to increase risk-aversion, less habit persistence is required to match mean asset returns, which simultaneously leads to lower volatility of the risk-free rate. However, Boldrin et al. (2001) point out that higher risk aversion also has adverse implications for employment

[29]The consumption volatility has dropped to 0.32. Basically, the agents in this economy use the near linear technology to smooth out consumption, counteracting the effect on risk premia that habit formation has on the preference side.

dynamics in such models.

1.3.5 Impulse Response Functions

To get insight into the workings of the model, the second part of our analysis concerns a set of impulse responses to a unit positive productivity shock. The impulse responses for this version of the model, under the baseline calibration in Table 1.1 are shown in Figure 1.2 and 1.3. In this kind of model the output and investment responses to unit positive productivity impulses are standard. The dividend responses show that the dividends are procyclical, as they are in the model's closed economy version. Indeed Jermann (1998) found that, even with and without habit, dividends are more procyclical with respect to capital adjustment costs. The marginal utility response is also in line with what can be found in a closed economy version of the model, and it is negatively serially correlated with a hump-shaped response. Consumption also displays a hump-shaped response because, under habit formation, households smooth both the level and the change in consumption. The peak of the consumption and marginal utility responses takes place after 10 quarters. Responses of the other variables to unit technology shocks correspond to literature standards.

1.4 Concluding Remarks

Prior research on endowment model following Lucas (1978) and Campbell (1986) has focussed on various modifications of a standard RBC model in an effort to resolve its puzzling pricing implications. In fact, the version of the RBC model containing habit persistence and capital adjustment costs properly accounts for equity premiums and other asset pricing components.

The same model however when augmented by a foreign sector fails to generate substantial equity premiums nor explain equity generated by historical data in small open economy cases.

Using the lognormal-loglinear model solution, in this chapter we evaluate asset prices in small open economy cases and highlight some shortcomings. First, as discussed above, the model generates low risk premia and its second shortcoming is that, consistent with the findings of Heaton (1995) and Boldrin et al. (1999) the volatility of the risk-free (and risky) rate is too high, This is a typical problem for those utility functions that display habit formation. Habit persistence makes marginal utility very volatile, even for smooth consumption profiles (Budría, 2002). This creates large fluctuations of the expected marginal utility at successive dates, and also involves large movements in the risk-free rate.

In summary, this model does well when compared to selected business cycle statistics, but fails to improve the performances obtained using the closed economy version of the model with respect to asset pricing. Obvious directions for future work include estimating the parameters used to generate the results, and finding features of technology that can prevent households from smoothing their consumption in an open economy model. Indeed, if we can limit the access to foreign debt (assets) the model obtained can allows one to solve for asset returns. These areas are a few of the many areas where further work might be focused in order to address the issue of best way to resolve the puzzle equity premium.

Tab. 1.1: Model Calibration

Parameter	value assigned
ρ_z	0.94436
σ_z	0.00599
β	0.96
$\bar{x}$	0.0040
α	0.32
b	0.58
δ	0.025
γ	2.0
ζ	1/0.23
φ	0.006

Tab. 1.2: Equity Premium Statistics

Statistics	Model	Data*
$E(r^e - r^f)$	0.0247	3.47
$\sigma(r^e - r^f)$	79.252	15.53
$\sigma(r^e)$	78.864	na
$\sigma(r^f)$	7.058	na
$\sigma(\Delta \ln(C))$	0.6822	2.04
$\rho(r^e - r^f, \Delta \ln(C))$	0.004782	0.33
$\text{cov}(r^e - r^f, \Delta \ln(C))$	0.2584	10.58

* Data statistics are from Allais et al.(2000)(we report the case of Canada).
Note : The first column represents the average excess return. The second and fifth column are the standard-errors of the excess return and the consumption growth. In the last two column the covariance and correlation coefficients between the excess return and the consumption growth are represented.
Moments are averages of 100 replications of length 500.

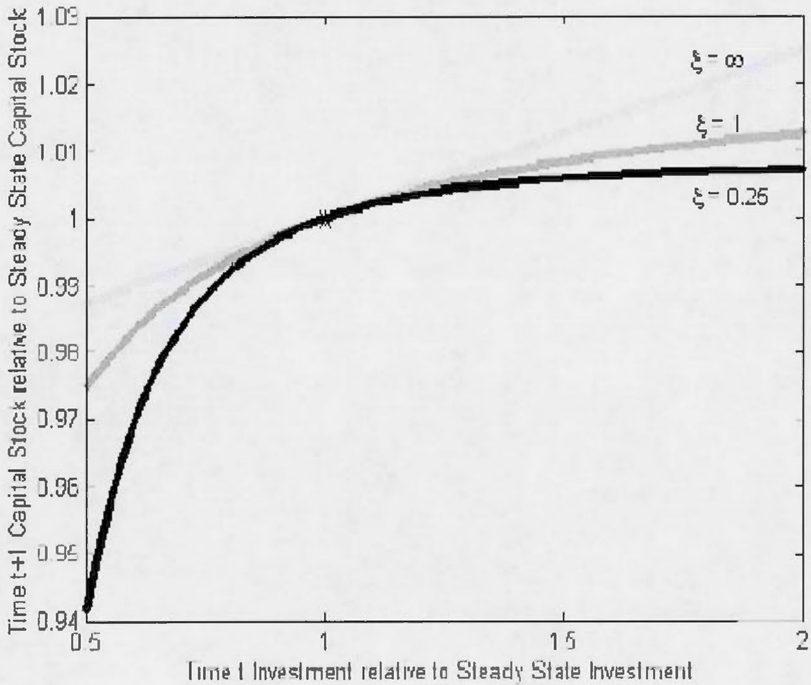
Tab. 1.3: Business cycle Statistics

Statistics	Model	Data*
σ_Y	1.78003	1.72
σ_C	0.31971	0.93
σ_I	2.18099	5.13
σ_{P^e}	1.50586	na
σ_D	1.52692	na
σ_C/σ_Y	0.17961	0.54
σ_I/σ_Y	1.22526	2.98
$\rho(Y, C)$	0.88255	0.80
$\rho(Y, I)$	0.99038	0.77

* Data statistics are taken from Letendre (2003).
Note : This study uses quarterly Canadian Data (from 1981Q1 to 2001Q4) filtered with HP (here we use the same filter for moment computations).

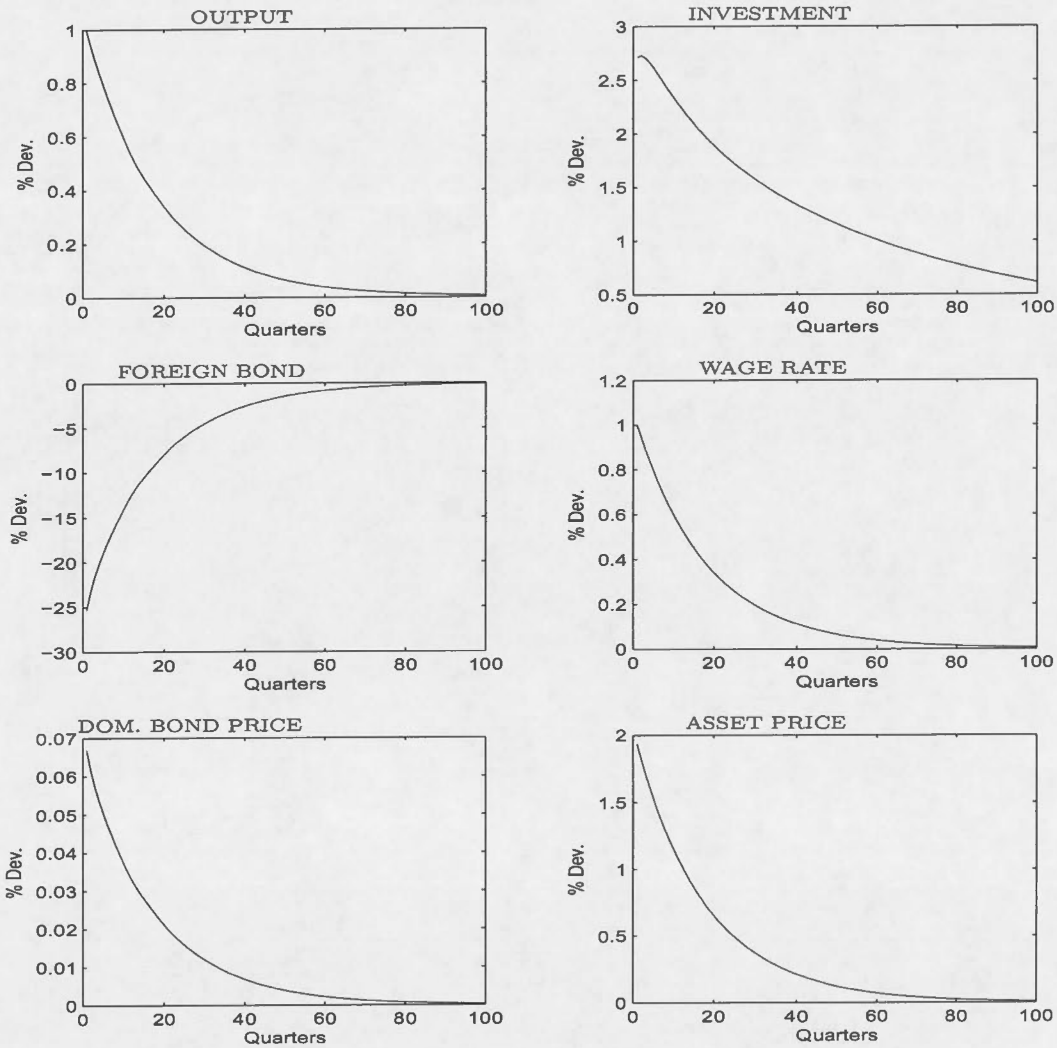
Fig. 1-1: The Cost of Adjustment Function

(Source : Budría, 2002)



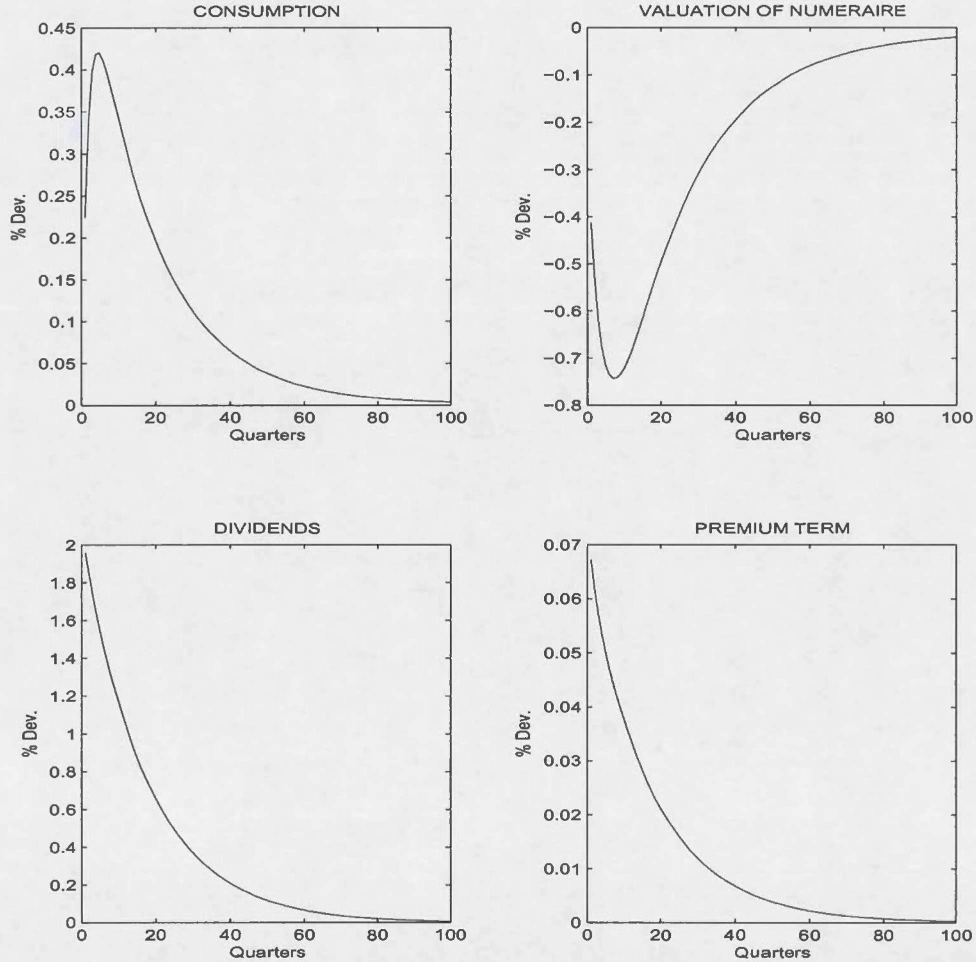
Note : This graphic is based on calibrations similar to what we use in our model.

Fig 2.2: Impulse Response Functions to a Unit Technology Shock



Note: The impulse is a unit positive productivity shock, the responses are in percent deviations from steady state values.

Fig 2.3: Impulse Response Functions to a Unit Technology Shock



Note : The valuation of numeraire is equivalent here to the marginal utility.

CHAPITRE II

THE MACROECONOMIC EFFECTS OF MONETARY POLICY AND FINANCIAL CRISIS

2.1 Introduction

There is a vast empirical literature regarding the effects of monetary policy on output and other macroeconomic aggregates. Indeed, considerable interest has been continually sustained among both policy makers and researchers regarding the sources of business cycle fluctuations, with emphasis being placed on various supply shocks and demand changes. Also, there is a rapidly growing literature that pays special attention to monetary policy shocks. A typical finding is that monetary shocks affect output with long delays, that their effect is highly persistent, and this accounts for the movement in aggregate price levels. Inferences that can be made however regarding the quantitative effects of monetary shocks critically depend on underlying identification and estimation schemes (Christiano, Eichenbaum, and Evans, 1999).

A monetary policy shock is defined as the portion central bank policy variation not caused by systematic responses to variations in the state of the economy. With this in mind, the purpose of this study is to determine whether monetary policy shocks have any effect on a real economy, while focusing on the economy's regular responses to shock behavior.

Furthermore, the identification of monetary shocks is not without controversy. Indeed, estimates made of the macroeconomic effects of monetary policy often differ from one study to the next with regard to both their timing and magnitude [see, for example, Christiano, Eichenbaum, and Evans (1994, 1999), Gordon and Leeper (1994) and Leeper, Sims, and Zha (1996)]. We thus examine whether major conclusions made by alternative specifications of our empirical model hold up. First, given that it is arguable whether monetary policy will respond to variables not already included in empirical work, we examine how controlling for other shocks (namely, market crashes and oil price changes) might alter the apparent real effects of monetary shocks. Second, controversy also exists as to whether monetary authorities should react to asset price movements. Similarly, we examine the effects of stock market crashes on the real economy. We begin our study by examining the exogeneity of both types of perturbations, and then analyze their implications on macro variables.

While the exogeneity of the monetary policy shocks is well documented in the literature, nothing has yet done regarding the new Romer and Romer (2004) measure and regarding stock market crashes. Given that their exogenous nature has been questioned, our objective here is to study the effects of the shocks – to monetary policy and stock market crashes – on various macro variables, and then assess the real effects of these shocks on the economy. The accuracy of estimates made of these effects depends essentially on the measures for monetary policy and stock market collapse variables being used. For the purposes of this study and in order to construct a dummy variable, we use the new US monetary policy shocks measure recently developed by Romer and Romer (2004) along with the dates highlighted by Mishkin and White (2002).

We also use a procedure that was first used by Leeper (1997) to study the exogeneity of the monetary dummies developed by Romer and Romer (1989, 1994).[1] This methodology combines the narrative approach with vector autoregression (VAR) in order to verify whether both shocks are contaminated by substantial endogenous components.

[1]Following this methodology, Leeper (1997) argues that the Romers' (1994) monetary dummy is not exogenous, meaning that this dummy is contaminated by a substantial endogenous component.

For this reason a logit equation for the financial dummy variable is estimated, after which we compute the probabilities that the dummy variable take the value one at the date selected by Mishkin and White (2002), using a narrative approach. Two VAR systems are then estimated, and finally the impulse response functions are analyzed.

Following Leeper (1997), the basic VAR has seven variables : industrial production (Y), consumer prices (P), the 3-month Treasury bill rate (R3), the 10-year U.S. Treasury bond yield (R10), total reserves (TR), the price of commodities (PCM) and finally monetary shocks or a market crash dummy. All variables are measured in logs except for interest rates, which are measured in percentage points.

First, we estimate two VARs, called 'Financial VAR' for the one incorporating the financial crisis variable, estimated over a sample period extending from 1960M01 to 2000M12 and 'Monetary VAR' for the new monetary policy measure built by Romer and Romer (2004), covering a period 1969M01 to 1996M12. Then, we incorporate the financial crash dummy and the monetary policy shock into the same VAR, combining them both to estimate the effects of each.

As was mentioned above, our measure of monetary shocks is the new measure developed recently by Romer and Romer (2004) which they based on their interpretation of the Federal Open Market Committee (FOMC) meeting reports, combined with information on Federal Reserve expected fund rates. See Figure 2.1 for the new monetary policy measure computed by the authors. For reasons of readability, the monthly values are converted into quarterly observations and display a continuous series, capturing changes in the intended movements in the fund rate around the FOMC meetings. The idea then is that this measure should be purged of the movements in the economy that are anticipated by the Fed, so that it reflects purely exogenous, unanticipated changes in monetary conditions.

Romer and Romer (2004) incorporate their monetary policy shock measure in a VAR, based on that of Christiano, Eichenbaum and Evans (1996). They estimate a three-variable VAR including output (measured by industrial production), producer price index (PPI for finished goods) and their new monetary policy measure. They find that monetary policy shocks have both strong and statistically significant effects on output. They also show that a negative monetary policy shock generates a strong, negative price response. They argue that their shock measure creates a stronger effect on output (see Christiano, Eichenbaum and Evans, 1996; Romer and Romer, 1994; Barth and Ramey, 2001 and Boivin, 2001).

As for stock market crashes,[2] we use the dates computed by Mishkin and White (2002). In the spirit of Hamilton (1983) and Romer and Romer (1989, 1994), the authors apply a narrative approach to identify the stock market collapses in the United States over the last one hundred years.

In their study, Mishkin and White (2002) argue that financial market crashes decrease aggregate demand through reducing wealth and raising the cost of capital. This may also reduce consumer spending and real investment.[3] Thus, stock market perturbations can produce additional stress on the economy,[4] possibly leading to intervention by the central bank. For example, the monetary authorities may react to movements in stock prices in order to stop bubbles from getting out of hand, or alternatively try to prop up the stock market following a crash through adopting an expansionary policy stronger than the one indicated by straightforward effects on aggregate macroeconomic variables (Mishkin and White, 2002). These strategies are applied only if stock market crashes have the potential to destabilize the financial system and to produce more stress on the economy.

Based on their historical analysis of all stock market crashes in the twentieth century in the United States, Mishkin and White (2002) identify major collapses of the financial

[2] Also called financial crisis in this work.

[3] Central banks, trying to conduct an optimal policy, should react to these fluctuations. The manner in which this reaction is related to the effect of stock market perturbations on aggregate demand is unclear (Mishkin and White, 2002).

[4] This stress should become visible in risk premiums on interest rates. Note that crashes are not always the main cause of financial instability. Collapses of banking systems or severity of economic contractions are also possible independent factors that could lead to financial instability (Mishkin and White 2002).

market. A stock market crash is defined here as a sudden dramatic loss of share value for corporate stocks. However, as highlighted by the authors, attempting a precise definition and measurement of stock market crashes over the century is a difficult task. Key factors include the stock market index, the size of the collapse and the duration of the crash. Indeed, using three stock indices[5] and the universally agreed stock market crashes of October 1929, and October 1987 as benchmarks, they identify 15 major financial crises in the last century.[6] Since we have limited our analysis to the US postwar period, we construct a dummy variable representing the dates identified by Mishkin and White (2002) and zero otherwise.[7] These dates[8] are : 1962 :04, 1970 :05, 1973 :11, 1987 :10, 1990 :08, and finally 2000 :04.

Our results show empirical evidence that both financial crises and monetary policy shocks are exogenous. These results remain relatively unchanged even when we include other exogenous shocks in the VAR or when different weights are given to financial crisis episodes.[9] Furthermore, the logit equation for the financial crisis dummy does not provide any meaningful help in explaining this shock's exogeneity, since it is imprecisely estimated and leads to puzzling probabilities.

These results suggest that it is important that monetary authorities take disruptions in the financial market into account when assessing monetary policy. Monetary authority responses to asset price movements is an expanded and ambitious mission for monetary policy, but it might complicate inflation targeting procedures. Indeed, monetary policy is a macroeconomic policy tool that should be used for macroeconomic

[5]The authors use monthly Dow Jones Industrials Index records, the Standard and Poor's 500 Index and finally the NASDAQ Composite Index to identify nominal crashes.

[6]A stock market crash is defined by a 20% drop in the market combined with the speed of the collapse by looking at declines over windows of time, where depth and speed are the main features that define it.

[7]With the stock market crash defined as a decline in stock prices, by construction the shocks highlighted by the authors are of the same sign. Depth and speed of collapse might be different but they have the same magnitudes.

[8]Since data used in our empirical study covers the period 1960M01 - 2000M12.

[9]Following the classification presented by Mishkin and White (2002), we assign different weights to financial collapses, varying from one to four, according to crash category.

purposes, not for single market, localized events, as in the financial market. However, as suggested by advocates of central bank intervention[10] (in case of financial crisis), asset price movements may lead to sizeable debt build-ups, weakened balance sheets and financial imbalance (Saxton, 2003). Such perturbations can generate financial instability and in turn, macroeconomic fluctuations.

The remainder of this chapter is structured as follows. Section 2.2 describes the econometric methodology we use to estimate the VAR systems. Section 2.3 discusses the econometric evidence on exogeneity for two kinds of shocks and presents the results. Section 2.4 presents the concluding remarks.

2.2 Econometric Methodology

The methodology implemented to investigate the exogeneity of different shocks follows the work done by Leeper (1997) and Horent (2002) in their examination of the exogenous effects of shocks on monetary and fiscal policy.

In our empirical work, VAR systems have seven variables : output, consumer prices, 3-month Treasury bill rate, 10-year Treasury bond yield, price of commodities, total reserves and finally the shock considered.[11] The variables are in levels rather than in first differences, even though the series may be either non-stationary or cointegrated. The estimates in this case yield consistent values for all parameters, as pointed out by Hamilton (1994) and Weise (1996), provided that the lags included in the estimation are long enough.

Enders (1995) and Lütkepohl (1991) show that in any VAR an important issue is the selection of an adequate lag length and appropriate time trend, and in this respect two main problems can be highlighted. First, if the lag length included in the system is too long, degrees of freedom are squandered. Second, the system may be mis-specified

[10]See Saxton (2003) for a survey of the literature on cases for or against central bank intervention in financial crises cases.

[11]See appendix B for more details about the data used in this work.

if the appropriate time trend is not included or if the lag length selected is too short; this may yield biased coefficient estimates and some autocorrelation problems.

2.2.1 Time Trend

In order to test for the presence of a time trend (linear and/or quadratic), we use the Akaike information criterion (AIC) and the Schwartz criterion (SIC). We test both a linear and a quadratic time trend and to determine which is more appropriate, with the most adequate specification being the one that minimizes criterion values.

We also make use of likelihood ratio (LR) statistics to test for a null for a no time trend or alternatively for a linear trend. Next we assess a restricted model with no trend, then an unrestricted model in which a linear and (or without) quadratic time trend are included in the VAR.[12]

The results show that including either a linear or quadratic time trend is better than not including a time trend in the VAR systems. Indeed, based on computations for the information AIC and SIC criteria, we conclude that the best choices are linear and quadratic time trends in financial and monetary VARs[13] (see Tables 2.1 and 2.2). Table 2.3 shows the results of the LR test on both VARs. The null hypothesis of the 'no trend' against the 'linear trend,' and alternately the 'linear and quadratic trend' are tested.

Note that including linear and quadratic trends does not significantly affect the results the two systems being studied, and furthermore the results are not sensitive to the addition of quadratic time trends. It is for this reason that in our empirical study we consider a linear time trend in both VARs.

[12]See Appendix C for more technical details on the formula used to compute the different criteria.
[13]SIC suggests no time trend in the monetary VAR.

2.2.2 Lag Length

We establish the optimal lag length using the information criteria. In fact, the Akaike information criterion (AIC) and Schwartz criterion (SIC) are used to determine the lag length for the variables included in the VAR systems. Models with various lag lengths are estimated, and the corresponding AIC and SIC values are computed.[14] The optimal lag length is the one that minimizes the information criterion values.[15]

The likelihood ratio (LR) is also used to validate the choice of AIC and SIC criteria. In their study Romer and Romer (2004) use 36 lags in the baseline specification for the monetary VAR.[16] Following Leeper (1997) and Romer and Romer (2004), we consider 36 lags as the maximum lag length for both systems. The null hypothesis of 36 lags versus 35 lags is tested. Then a restricted model with 35 lagged values for the variables in VAR is then estimated, followed by an unrestricted model with 36 lags, and finally the likelihood ratio statistics are computed.[17] If the likelihood ratio exceeds the critical value for the χ^2 distribution, at 5% significance level, the null for the 35 lags can be rejected, and the model with 36 lags would be preferred. Otherwise, the null for 34 lags against the alternative of 35 lags is tested. The same procedure is repeated until a null hypothesis is rejected.[18]

Tables 2.4 to 2.6 display the results of the optimal lag length selection for the VAR system variables (financial and monetary), as well as an appropriate time trend.

Table 2.4 lists the Likelihood Ratio (LR), AIC and SIC tests carried out. It also indicates that AIC suggests 8 lags in the financial VAR and 36 lags in the monetary

[14]Lags from 1 to 36 are included following Leeper (1997), who use 36 lags for the dummy variable and 24 lags for macro variables. Here we use the maximum lag length to test for the optimal one.

[15]It should be noted here that various Monte Carlo studies usually compare the lag order selection criterion to find out which one would be best able to select the true log order most often (Nickelsburg, 1985, Kilian, 2001). The lag order distribution results may be of theoretical interest, but they are of limited interest for applied users interested in VAR statistics such as forecasts or impulse responses, as shown by Kilian (2001).

[16]See Appendix C for technical discussion about LR, AIC and SIC

[17]It has an asymptotic χ^2 distribution with degrees of freedom equal to the number of restrictions (one restriction per equation, which is seven for this test).

[18]We consider only those models whose endogenous and dummy variables have the same lag lengths.

VAR, while on the other hand LR suggests up to 36 and 21 lags in the financial and monetary VAR respectively, while SIC implies that including 1 lag is even better for both systems.

This statistical evidence leads to different conclusions regarding the optimal lag length for the two VARs. Based on the SIC, it seems better to include one lag for the endogenous variables in the two systems. However, the AIC suggests 8 lags for the financial VAR and 36 for the monetary system. LR found that 36 and 21 lags for financial and monetary systems is better respectively.

Empirically, Killian (2001) presents a Monte Carlo study and concludes that the AIC has better finite sample proprieties when compared to other optimal lag length selection criteria. Horent (2002) presents the same evidence by using impulse response functions to compare models where lag length order is selected based on different criteria.

This section provides evidence as to which optimal lag length and time trend specification would be best used to estimate the systems under study. In what follows, as suggested by the AIC, in Tables 2.5 and 2.6 we consider a linear trend in both VARs.[19] Eight lags for macroeconomic variables and financial dummy variables are used in estimating the financial VAR. We use up to 36 lags for the monetary VAR, and include a constant term and seasonal dummy variables in our estimation.

2.3 Econometric Evidence

2.3.1 Shock Exogeneity

Previous discussions neglect an obvious question as to whether the shocks studied are exogenous, in the sense that may or may not be determined outside the system.

[19]The inclusion of a quadratic time trend in VAR systems does not significantly change results.

There are various notions of exogeneity and different ways to test for it.[20]

In our study we have two kinds of shocks : monetary shocks and financial crisis shocks. Despite the fact that the exogeneity of monetary policy can be tested using standard methods, the exogeneity of any dummy variable is more problematic. Leeper (1997) suggests constructing a logit equation in order to establish a binary variable's exogeneity.

To provide a understanding of the difference between the two methods, we consider the following VAR model with exogenous variables :

$$Y_t = a_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{q} \alpha_j X_{t-j} + U_t \tag{2.1}$$

where X_t is a vector of exogenous variables, with the crucial condition being that

$$E(U_t | \{Y_{t-i}\}_{i=1}^{\infty}, \{X_{t-j}\}_{j=1}^{\infty}) = 0.$$

Next, assuming a VAR presentation for X_t itself, i.e.

$$X_t = b_0 + \sum_{i=1}^{r} \lambda_i X_{t-i} + V_t, \text{ with } E(V_t | \{Y_{t-i}\}_{i=1}^{\infty}, \{X_{t-j}\}_{j=1}^{\infty}) = 0. \tag{2.2}$$

Assuming that $r = q = p$, the model reduces to a VAR(p) representation

$$\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} a_0 \\ b_0 \end{pmatrix} + \begin{pmatrix} \beta_1 & \alpha_1 \\ \mu_1 & \lambda_1 \end{pmatrix} \begin{pmatrix} Y_{t-1} \\ X_{t-1} \end{pmatrix} + \ldots + \begin{pmatrix} \beta_p & \alpha_p \\ \mu_p & \lambda_p \end{pmatrix} \begin{pmatrix} Y_{t-p} \\ X_{t-p} \end{pmatrix} + \begin{pmatrix} U_t \\ V_t \end{pmatrix} \tag{2.3}$$

with the assumption that errors are i.i.d normally distributed

$$\begin{pmatrix} U_t \\ V_t \end{pmatrix} \sim i.i.d\ N[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix}].$$

[20]Indeed, exogeneity, predetermination and causality are three quite different things. Tests for causality can be used to refute or not refute strict exogeneity but not to establish it.

Here we impose a restriction whereby $\mu_i = 0$, for $i = 1, ..., p$, implying that Y_t does not appear in the X_t equation or say Y_t does not Granger-cause X_t, which is a weak form of exogeneity. Strong exogeneity requires in addition to weak exogeneity that $\Sigma_{12} = 0$ and thus $\Sigma_{12} = \Sigma_{21} = 0$. In other words, this means that the error vectors U_t and V_t are independent. Testing for weak exogeneity is thus the first steep along the way. The null hypothesis is then given by $H_0 : \mu_1 = \mu_2 = ... = \mu_p = 0$. We then introduce the following variance-covariance matrix

$$\begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix} = \begin{pmatrix} L_{11} & 0 \\ L_{21} & L_{22} \end{pmatrix} \begin{pmatrix} L_{11} & 0 \\ L_{21} & L_{22} \end{pmatrix}' = LL', \tag{2.4}$$

and test the null hypothesis for strong exogeneity, as given below

$$H_0 : L_{21} = 0,$$

which completes the standard approach to testing for exogeneity.

The alternative is to use Leeper's (1997) method, whereby a logit equation is estimated for the dummy financial crisis, in order to check for exogeneity. Let X_t represent the list of independent macro variables. The expectation of the dummy financial variable (D_t), conditional on the information set Ω_t[21] is then

$$E(D_t|\Omega_t) = F(\eta, \beta(L)X_t), \tag{2.5}$$

where $F(.)$ is the logistic function, $\beta(L) = \beta_1(L) + \beta_2(L^2) + ... + \beta_m(L^m)$, L is the lag operator and η includes the constant and the time trend.

The methodology is as follows. First, we estimate the logit equation including all macro variables for the financial dummy variable. Then, we compute the probabilities that the logit equation has the value one at the dates selected by Mishkin and White (2002).

[21]The time t information set includes variables dated t-1 and earlier.

The logit equation being considered here includes three lagged values for the independent variable and a constant, a time trend, as well as seasonal dummy variables as dependent variables. Table 2.7 displays the coefficients estimated using the logit equation. This equation appears to be imprecisely estimated and none of the individual coefficients is significant (except for some seasonal dummy variables), even at the ten percent significance level.[22] Table 2.8 shows the probability predicted by the logit equation, and Figure 2.2 plots the predicted value against the actual value for the dummy variable.

The conditional expectation for the last financial crisis (2000M04) is puzzling. The predicted probability for this event is 81.77%, implying that the financial crash, which is believed to be unexpected, was predictable from the data. This result has to be taken with precaution,[23] given that the logit equation is imprecisely estimated and the value of parameters might affect the predicted probability. We therefore conclude that the logit approach does not help in providing evidence about the financial crisis variable's exogeneity.[24]

Following Leeper (1997), an alternative approach is to consider two linear systems[25] in which the dummy variable is entered in the VAR as an endogenous variable, and then identify the shocks to financial crisis by the Cholesky decomposition. For the first VAR (VARF1), the financial dummy is ordered first, output is ordered second, followed by price, interest rates (R3 and R10), price of commodities and finally total reserves plus a constant, with a time trend and seasonal variables being deterministic variables. It is assumed here that the shock to the financial dummy may have contemporaneous effects

[22]Including more than 3 lagged values for the macro variables leads to non-convergence even when the seasonal variables are not included in the logit estimation. Similarly, Leeper (1997) includes 18 lags for the endogenous variables when estimating the VAR, but only 6 lags when estimating the logit equation.

[23]Considering two lags in the logit equation decreases the conditional expectation for the last financial crisis (2000M04) to 13.09.

[24]Horent (2002) presents the same evidence about this approach when studying the Ramey and Shapiro (1997) dummy variable.

[25]Leeper (1997) points out some potential problems with the VAR systems including dummy variables as endogenous. Indeed, the predicted value for the dummy variable may lie outside the $[0, 1]$ interval, and regarding the dichotomous nature of the dummy, the relation between this and other system variables may be not linear. In our empirical study, the predicted value for the financial crisis dummy variable, computed for the financial VAR, lies within the $[0, 1]$ interval.

on the other variables. However, shocks to macro variables do not have the same effect on the financial dummy. This can suggest that the financial crises are independent of the current state of the economy.

In the second VAR (VARF2), output is ordered first, price is ordered second, followed by the price of commodities and total reserves, then the financial dummy is ordered fifth and the interest rates (R3 and R10) are ordered last. The assumption behind this ordering is that shocks to output, price, price of commodities and total reserves have a contemporaneous effect on shocks to the financial crisis variable. The shocks to the dummy variable have contemporaneous effects only on interest rate innovations.

As highlighted by Horent (2002) in analyzing the Ramey and Shapiro (1997) dummy variable, it is difficult to justify the last assumption. Indeed, assuming that shocks to the financial dummy have contemporaneous effects on some macro variables and not on others is a strong assumption. However, if the dummy variable is truly exogenous, the impulse response functions (IRF) computed using the VAR in which the dummy variable is endogenous should not be affected by the ordering of innovations in the Cholesky decomposition.

Figure 2.3 shows the impulse response functions (IRFs) computed from VARF1 and VARF2. IRFs are then plotted for output, price, interest rates R3 and R10, price of commodities and total reserves for shocks to the financial crisis variable, with the Cholesky decomposition. The solid lines display the IRFs when VARF1 is estimated and the dashed lines the impulses for the VARF2. The 68% confidence intervals are computed using 2500 replications of the Monte Carlo experiments, using the VARF1.

All the IRFs computed for both VARs lie within the confidence intervals from the financial VAR, and the IRFs from VARF1 and VARF2 exhibit very similar patterns. Even though the ordering in the Cholesky decomposition does not affect the IRFs computed, overall the point estimates of the IRFs computed for VARF1 are close to the corresponding point estimates reported for VARF2.

The two linear systems are estimated following the methodology used in Leeper (1997) to examine the exogeneity of the financial crisis dummy variable, where this dummy is entered as an endogenous variable, using the Cholesky decomposition with different ordering for each VAR, and then computing IRFs. This suggests that the financial collapses are exogenous,[26] and thus we can conclude that the results reported for the linear systems are consistent with the fact that the financial crisis episodes are exogenous.

The standard method is used to test the exogeneity of the monetary policy shock. Table 2.10 presents the results on Granger causality test, showing that apart from the interest rates (R3 and R10) and total reserves (TR), we cannot reject the null hypothesis of the no causality. According to Granger, at the 5% significance level causality in the Granger sense cannot be established between the other macro variables and the monetary shock.

As was mentioned in Subsection 2.3.1, we estimate two VARs in order to test for weak exogeneity. In this model we impose the restriction that the macroeconomic variables do not appear in the monetary shock equation, so that all the coefficients μ_i are equal to zero.[27] We then compute the LR statistic and the results shown in Table 2.9 show that the null hypothesis cannot be rejected at the 5% significance level (not even at the 1%). In this case the monetary policy measure would be weakly exogenous.

Furthermore, using the Cholesky decomposition we conclude that the new monetary policy shock measure is exogenous, even when including more macro variables than those used by Romer and Romer (2004)[28] to assess this view. Indeed for the two VARs, Figure 2.4 shows the IRFs for output, price, interest rates R3 and R10, price of commodities, and total reserves. In the first one (VARM1, a solid line in Figure 2.4), the monetary

[26]As mentioned by Florent (2002), introducing a logit equation in a linear system and replacing the linear equation for a dummy variable leads to a lack of significance for the results retrieved from the non-linear system. The results of this substitution are not presented here.

[27]In the monetary shock equation (in the restricted VAR) only this variable's lags are entered as explanatory variables, along with constant term, time trend and seasonal variables.

[28]The specification used by the authors includes industrial production, the PPI for finished goods and the new monetary policy measure.

policy shock is ordered first, followed by the macro variables. These suggest independence between monetary policy measures and the current state of nature innovations on macro variables.

In the second VAR (VARM2, long dashed lines in Figure 2.4), output is ordered first for the Cholesky decomposition, and then prices, commodity prices, total reserves,the monetary shock, and finally the interest rates R3 and R10. The same assumptions used for the financial crisis are applied here. Then the innovations to output, price, commodities and total reserves have a contemporaneous effect on innovations to monetary policy, but the monetary shocks have contemporaneous effects only on interest rates innovations.

The IRF for output (in Figure 2.4) computed for VARM2 lies slightly above the 68% confidence interval from monetary VAR[29] (VARM1) for 8 periods. Then it lies very slightly below the lower bound for the next 18 periods after the shock. After that it lies within the confidence interval. The IRF for consumer prices lies below the confidence interval after 19 months.

The response of R3 computed for VARM2 lies above the upper bound for 7 months and then lies within the confidence interval until period 16, and then it lies within the confidence interval. The some response is displayed by R10. The IRF for PC and TR lies slightly below the confidence interval for almost all periods.

However, the point estimates of the IRFs computed for the second linear system are close to the corresponding point estimates reported for the first linear system and the patterns for the two VARs (with different Cholesky ordering) are quite similar to each other for all variables.

Overall, the IRFs reported for the monetary policy shock are consistent with the new monetary measure being exogenous. Thus, as mentioned by Romer and Romer (2004), the monetary policy shock is relatively free of both the endogenous and anticipatory

[29]2500 Monte Carlo replications of VARM1 are used to compute the 68% confidence interval.

actions of the monetary authorities.

2.3.2 Impulse Response Functions

The implications of financial crisis shocks and monetary policy measures in VAR systems, and the isolation of macroeconomic effects of both shocks pass through the impulse response functions (IRFs) analysis. This process focuses on financial and monetary VAR systems estimation and then the IRFs -showing the effects of a unit shock to each variable of interest on macro variables- are computed.

Results from financial VAR estimates are shown in Figure 2.5. The responses to a unit shock on financial crisis innovations are plotted, along with their standard error bounds, computed using 2500 Monte Carlo replications using financial VAR. The output response is characterized by a decline, reaching its maximum (-5.8%) at month 16 after the shock and then returning to its initial level. This response is similar to that found by Leeper (1997), Sims (1980), Litterman and Weiss (1985) and others regarding the impact of monetary policy contractions on production. They argue that there is evidence that these perturbations can reduce nominal aggregate demand and lower output when prices adjust sluggishly (Bernanke and Blinder, 1992). However, there is only one direct link between stock market collapses and monetary policy through the financial instability as pointed out in Mishkin (1997) and not all crashes are followed by signs of financial instability (Mishkin and White, 2002).

The impulse response to consumer prices implied by the financial VAR is small and insignificant for the first 10 months, and then becomes more significant, although modestly positive. The responses to interest rates are negative for almost all periods. The Treasury Bill rate (R3) rises for the 3 first periods, falls rapidly to reach its maximum decline (-2.2 points) at month 25 and then returns slowly to its initial value. The response to the Treasury bond yield (R10) is negative with a maximum effect of -1.3 points at period 24. The IRF for commodity prices rises by 55% for the first 2 months and then begins to fall, reaching its maximum decline (-2%) at month 8 and then becoming positive after period 10. After period 12 the IRF for total reserves shows a small positive value but a consistent response.

Plotted in Figure 2.6 are macro variable responses to a unit shock to the monetary policy variable. Solid lines show point estimates and short dashed lines are standard error bands, computed with 2500 Monte Carlo experiment replications using monetary VAR.

The output response increases for three periods then it falls. The maximum decline is about 3.5%, and is attained at month 15, and then it returns back to its initial level. Romer and Romer (2004) found that the output response has its peak effect at about -2.9%, relatively the same thing as we get here. However, the inclusion of more macro variables leads to a change in the output response function, increasing to a positive value through month 37 after the shock. Output returns to its initial value, as in the Romer study.

The response of consumer prices is similar to that reported in the Romer study. Indeed, the IRF of price is small, irregular for 12 periods and then negative. The IRF computed for interest rates responding to a unit shock for the monetary policy variable are quite standard. They are positive for the first 12 periods, they reach 1 point at a maximum increase for R3, and after that become negative. The IRF for R10 is similar to the R3 response for the 14 first periods, then they become negative and fairly flat.

The commodity prices show an irregular response until period 22 when they become negative, while reserves rise for the first 2 periods, then become negative and irregular until month 23, and finally fall sharply to become negative and slowly return toward their initial level.

Figure 2.7 shows impulse responses to a one unit shock to the innovations of a financial dummy variable when treated as exogenous in estimating a financial VAR. The responses are generally similar to those reported for the VAR when the dummy variable is treated as endogenous, apart from the magnitudes which are more important when financial collapses are estimated exogenously in the VAR system.

The same conclusion applies when the monetary policy variable is treated as exogenous. Figure 2.8 displays the IRFs for the variables in the monetary VAR. The responses are relatively similar to those reported early (Figure 2.6), confirming the view that both of these variables (monetary policy and stock market crisis dummy) are exogenous.

In conclusion, the effect of monetary policy and stock market crisis variables on real economic activity is extensive and statistically significant. About the same results are obtained at Romer and Romer (2004) in their VAR analysis, including only 3 macro variables.[30] This is somehow consistent with the idea that monetary policy shock has a temporary negative and persistent effect on output, as implied by the impulse responses of structural VAR systems.[31]

The hump-shaped short-run output dynamics following monetary policy contractions and stock market collapses suggest that both shocks have real effects on economic activity. As such, monetary authorities have to take these facts into account when developing an optimal policy.

2.3.3 Extended Model

The monetary policy and the financial crisis episodes may be characterized not only by a shock to monetary policy or financial sector collapse, but also by non-systematic changes in other sectors of the economy, say by other exogenous shocks. We therefore examine the effects that other shocks may have on the results reported for the two main shocks considered here (monetary and financial crisis shocks).

The model constructed includes Hamilton's oil price shocks.[32] Using the dates iden-

[30] The Romers basic VAR includes only output, price and the monetary policy measure as endogenous variables.

[31] See Bernanke and Blinder (1992), Sims (1992), Strongin (1995), Bernanke and Mihov (1998), Bagliano and Favero (1998), and Christiano, Eichenbaum and Evans (1999).

[32] The Ramey and Shapiro (1997) dummy variable is not included in the system because of data limitation (the Romer's monetary measure begin 1969M01). Indeed, the Korean War which was known

tified by Hamilton (1983), updated by Hoover and Perez (1994) and also Ramey and Shapiro (1997), we construct a dummy variable that has the value one at the shock dates : 1969M01, 1970M04, 1974M01, 1979M03, 1981M01 and 1990M03, and takes the value zero otherwise.

The VAR constructed includes the macro variables and three shocks (monetary, financial crisis and oil price shocks). Optimal lag length and an adequate time trend are also included. Thus, to examine the effects that exogenous shocks may have on the results reported for shocks to the financial crisis variable, a VAR including these perturbations as exogenous variables is estimated.

Figure 2.9 shows point estimates of responses for output, consumer prices, interest rates (R3 and R10), commodity prices and total reserves. The solid lines display point estimates for the IRFs and dashed lines display the 68% confidence interval.

The IRFs presented when other exogenous shocks are included to estimate the financial VAR indicate that results reported for price, interest rates and relative commodity prices are not very affected. The output response falls persistently and then becomes flat, reaching -12% declines 3 years after the shock. The IRF for total reserves is negative for a whole period.

Additionally, estimating a financial VAR with only two shocks, say the Hamilton oil price dummy and the financial crisis variable, suggests that macro variables responses remain relatively unchanged. Indeed, Figure 2.10 shows that the output responses are the same as in the standard financial VAR until month 27, when it became insignificant. The price IRF is weakly negative, and then significantly positive through period 32. The responses for the other variables are relatively the same as in standard financial VAR.

Furthermore, the magnitude of the effect of a shock to financial crisis is significantly similar to that reported for the standard financial VAR, and the pattern of the effect is very similar. Thus, it does not appear that the inclusion of other exogenous shocks

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to have important effects on macro variables cannot be included in our sample period. This loss of information can significantly affect the results obtained.

substantially alters the results reported earlier. Figure 2.11 shows evidence of the effect of the Romer monetary policy variable in a model that alternatively includes financial crisis and oil price shocks as exogenous variables. The IRFs computed for output, price, interest rates, commodity prices and reserves are responses to a one unit shock on monetary policy variable. The solid lines display the point estimate and dashed lines display the 68% confidence interval. Figure 2.12 shows the IRFs from monetary VAR, including only the Hamilton oil price dummy, which was used in order to isolate the effects of this variable on the responses given by the monetary policy variable. All the IRFs computed for the monetary system including other exogenous shocks are relatively similar to those reported earlier for the standard monetary VAR, apart from the total reserves variable (for the system including all shocks), which becomes negative for a whole period. Thus it appears that this last variable is affected by the inclusion of all shocks in VAR estimates. Therefore, it is concluded that the results reported for the monetary policy system variable are not sensitive to the addition of other shocks, confirming the view that this shock is exogenous.

Furthermore, to investigate the impact of the size given to the financial crisis episodes, we construct a weighted financial variable to which we assign a different weight to each crash, following the classification given by Mishkin and White (2002). Indeed, the authors place them into four categories depending on whether or not the episodes appear to place (or not) stress on the financial system.[33] Figure 2.13 shows the IRFs computed for output, price, interest rates, commodity prices and reserves as responses to a one unit shock on a weighted financial variable. The patterns for the IRFs are relatively the same, thus it does not appear that the size attributed to financial episodes alters results reported early in any substantial way.

[33]The classification is as follows :
- Category 1 : episodes 1962 and 2000 (weight = 1),
- Category 2 : episode 1987 (weight = 2),
- Category 3 : episode 1974 (weight = 4),
- Category 4 : episodes 1969-70 and 1990 (weight = 3).

2.4 Conclusion

Many previous studies on the effects of monetary policy shocks on macroeconomic aggregates have used alternative methods of identifying these policy shocks and have employed different VAR systems and sample periods in their analyses. Moreover, recently there has been considerable discussion regarding the appropriate monetary policy selected during the aftermath of a financial crisis. This suggests that there is a relation between monetary policy and financial stability, but there is still no clear consensus on how one affects the other. As pointed out in Mishkin and White (2002), the key problem facing monetary policymakers is not stock market crashes, but rather financial instability. Indeed, not all stock market collapses are associated with financial instability, for they also arise from other sources such as a banking system crisis.

In this chapter we study the new monetary policy measure constructed by Romer and Romer (2004) in combination with a stock market crash measure based on dates highlighted by Mishkin and White (2002), in order to test whether these shocks are exogenous. The impulse response functions for the monetary and financial model reveal that monetary policy and financial shocks considered in this study have significant effects respectively on output, price level and on other variables.

Our results also show that even when including more macro variables than those used by Romers' study, we found the new measure to be exogenous. Then, by applying the statistical methodology used by Leeper (1997), we conclude that both shocks are truly exogenous. This suggests that the central bank has to take the effects of financial collapses into account when conducting monetary policy, even when targeting price stability. The link between both targets is unclear to some extent, and more research in this direction has to be conducted.

Tab. 2.1: AIC and SIC for Time Trend in Financial VAR

Financial VAR (1960M01-2000M12)

Type of Trend	Akaike Criterion	Schwarz Criterion
No time trend	-28.07880	-26.94209
Linear time trend	-28.13752	-26.94098
Linear and quadratic time trend	-28.21531**	-26.95894**

** indicates selection of the criterion.

Tab. 2.2: AIC and SIC for Time Trend in Monetary VAR

Monetary VAR (1969M01-1996M12)

Type of Trend	Akaike Criterion	Schwarz Criterion
No time trend	-26.09796	-24.58702**
Linear time trend	-26.14461	-24.55414
Linear and quadratic time trend	-26.17300**	-24.50302

** indicates selection of the criterion.

Tab. 2.3 : Likelihood Ratio Test for Time Trend Specifications

Hypothesis		Financial VAR (1960M01-2000M12)		Monetary VAR (1969M01-1996M12)	
Null Hypothesis	Alternative	LR value	P-value	LR value	P-value
No time trend	Linear time trend	40.954*	0.00018	104.0352*	0.0000075
No time trend	Linear and quadratic trend	82.616**	0.00000	109.7788**	0.0000147
Linear time trend	Linear and quadratic trend	41.662*	0.00000	106.9916*	0.0000333

* We impose 7 restrictions in this case, and the $\chi^2(7)$ at 5% significance level is 14.10.

** Up to 14 restrictions imposed, and $\chi^2(14)$ at 5% significance level is 23.70.

Tab. 2.4 : AIC, SIC and LR Statistics for Various Lag Lengths

	Financial VAR (1960M01-2000M12)			Monetary VAR (1969M01-1996M12)		
Number of lag	AIC	SIC	LR	AIC	SIC	LR
0	-7.406757	-6.582698	NA	-6.188355	-5.154554	NA
1	-28.07865	-26.81086*	9085.964	-26.14461	-24.55414*	6398.342
2	-28.37954	-26.66803	220.9674	-26.26522	-24.11810	127.3961
3	-28.50133	-26.34610	141.9524	-26.33706	-23.63328	109.7788
4	-28.48635	-25.88740	82.96758	-26.26854	-23.00809	65.82591
5	-28.52532	-25.48264	103.5194	-26.28649	-22.46938	89.17110
6	-28.51173	-25.02533	80.72046	-26.28649	-21.91272	81.95772
7	-28.56804	-24.63791	106.7733	-26.30366	-21.37323	84.62167
8	-28.67460*	-24.30074	124.2710	-26.28576	-20.79866	73.09499
21	-28.34826	-18.20599	57.76975	-26.45829	-13.73458	74.42541*
22	-28.26722	-17.68123	38.69207	-26.45844	-13.17807	49.31751
35	-28.17330	-11.37516	38.71227	-28.35452	-7.837544	49.98234
36	-28.33299	-11.09113	68.63871*	-28.63860*	-7.564961	40.87790

* indicates selection of the criterion.

Tab. 2.5: AIC Values for Various Lag Lengths and Trend Specifications (FV)
Financial VAR (1960M01-2000M12)

Number of lag	No trend	Linear trend	Linear and quadratic trend
0	0.001422	-7.406757	-8.871593
1	-28.01935	-28.07865	-28.16509
2	-28.35311	-28.37954	-28.44960
3	-28.46500	-28.50133	-28.55322
4	-28.44977	-28.48635	-28.55049
5	-28.48763	-28.52532	-28.58268
6	-28.48231	-28.51173	-28.56402
7	-28.51179	-28.56804	-28.60942
8	-28.60547	-28.67460	-28.70526**

** indicates selection of the criterion.

Tab. 2.6: AIC Values for Various Lag Lengths and Trend Specifications (MV)
Monetary VAR (1969M01-1996M12)

Number of lag	No trend	Linear trend	Linear and quadratic trend
0	0.001422	-7.406757	-8.871593
1	-28.01935	-28.07865	-28.16509
2	-28.35311	-28.37954	-28.44960
3	-28.46500	-28.50133	-28.55322
4	-28.44977	-28.48635	-28.55049
5	-28.48763	-28.52532	-28.58268
6	-28.48231	-28.51173	-28.56402
7	-28.51179	-28.56804	-28.60942
8	-28.60547	-28.67460	-28.70526**

** indicates selection of the criterion.

Tab. 2.7: Estimation Results for Logit Equation
(Data : 1960M05-2000M12)

Variables	Coefficients Estimate	Standard Error	T-Statistic
Constant	8.94	198.96	0.04494
CRISIS{1}	-28.45	117.63	-2.42533e-06
CRISIS{2}	-22.04	916.97	-2.40463e-06
CRISIS{3}	-26.81	104.67	-2.56014e-06
Y{1}	24.75	72.86	0.33966
Y{2}	151.48	134.47	1.12650
Y{3}	-181.72	103.62	-1.75373
P{1}	387.46	347.54	1.11486
P{2}	30.74	505.52	0.06081
P{3}	-401.77	393.09	-1.02208
PC{1}	-32.78	43.86	-0.74730
PC{2}	-19.32	71.39	-0.27057
PC{3}	42.28	38.22	1.10627
R3{1}	-5.78	3.76	-1.53638
R3{2}	6.79	4.49	1.51061
R3{3}	-1.58	2.33	-0.67912
R10{1}	6.91	4.26	1.62379
R10{2}	-11.32	7.00	-1.61837
R10{3}	4.54	4.25	1.06788
TR{1}	104.54	175.57	0.59543
TR{2}	-532.80	261.65	-2.03631
TR{3}	417.46	180.61	2.31139

Tab. 2.8: Conditional Expectation Computed from the Logit Equation
(Data : 1960M01-2000M12)

Date Episodes	Predicted Probability (percent)
1962M04	10.02
1970M05	23.59
1973M11	51.55
1987M10	11.52
1990M08	2.57
2000M04	81.77

Tab. 2.9: LR Test for Weak Exogeneity of Monetary Shocks
Joint Weak Exogeneity Test

	Value
Log Likelihood For restricted VAR	-786.4347
Log Likelihood For unrestricted VAR	-786.4344
LR Statistic	0.0006
Critical Value at 5% level ($\chi^2(90)$)	113.1

Tab. 2.10 : Granger Causality Test

Monetary Policy Shocks (Data : 1969M01-1996M12)

Null Hypothesis	F-Statistic	Probability
Monetary Shock does not Granger Cause Y	2.99482	0.00016
Y does not Granger Cause Monetary Shock	1.35341	0.16842
Monetary Shock does not Granger Cause P	1.40780	0.14084
P does not Granger Cause Monetary Shock	1.62567	0.06514
Monetary Shock does not Granger Cause R3	5.40863	8.1E-10
R3 does not Granger Cause Monetary Shock	1.82960	0.02962
Monetary Shock does not Granger Cause R10	2.57655	0.00114
R10 does not Granger Cause Monetary Shock	2.80366	0.00039
Monetary Shock does not Granger Cause PC	0.39860	0.97907
PC does not Granger Cause Monetary Shock	1.07133	0.38207
Monetary Shock does not Granger Cause TR	2.12530	0.00865
TR does not Granger Cause Monetary Shock	1.99577	0.01500

Fig. 2-1: Romer and Romer (2004) New Measure of Monetary Policy Shocks

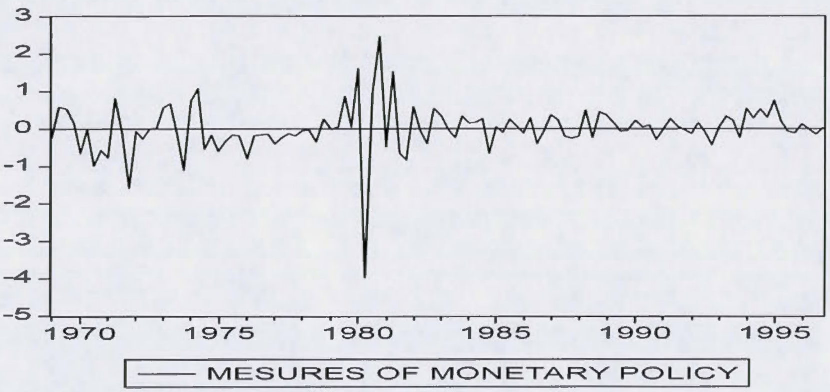


Fig. 2-2: Predicted Values from Logit Equation Vs. Actual Dummy

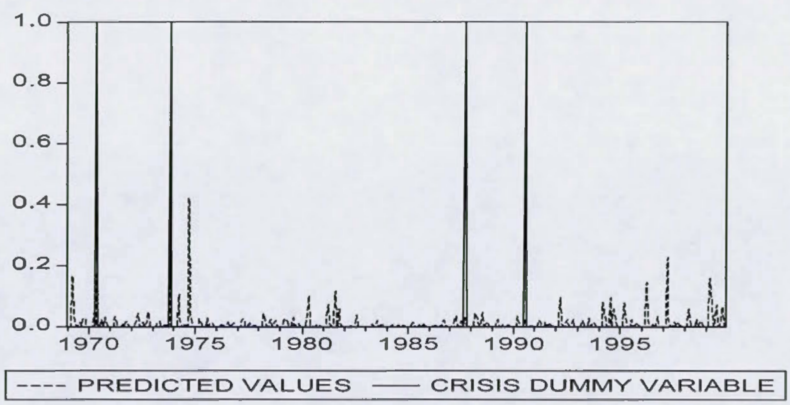


Fig. 2-3: Responses to Unit Shock in Stock Market Crisis with Cholesky Decompositions

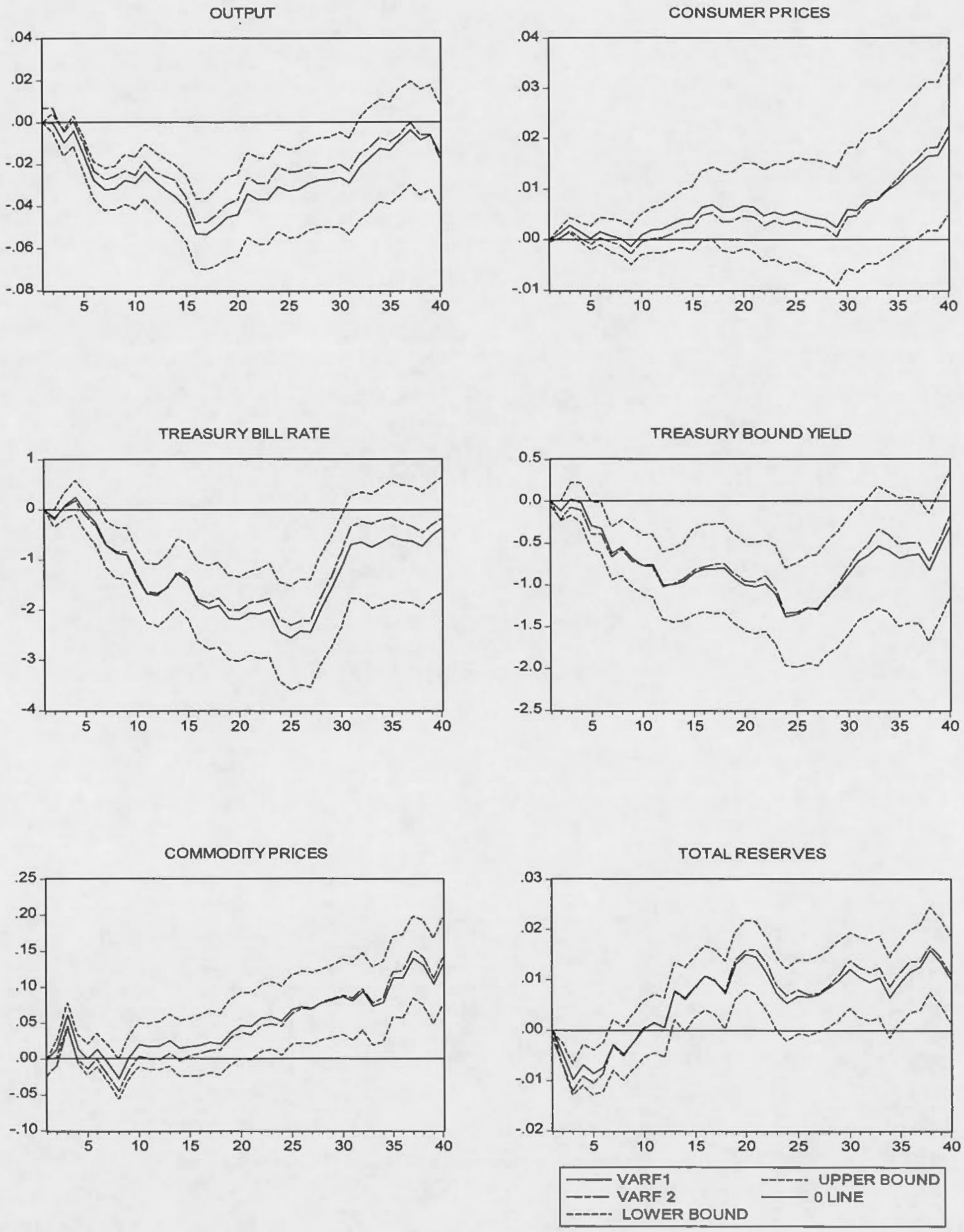


Fig. 2-4: Responses to Monetary Shock with Cholesky Decompositions

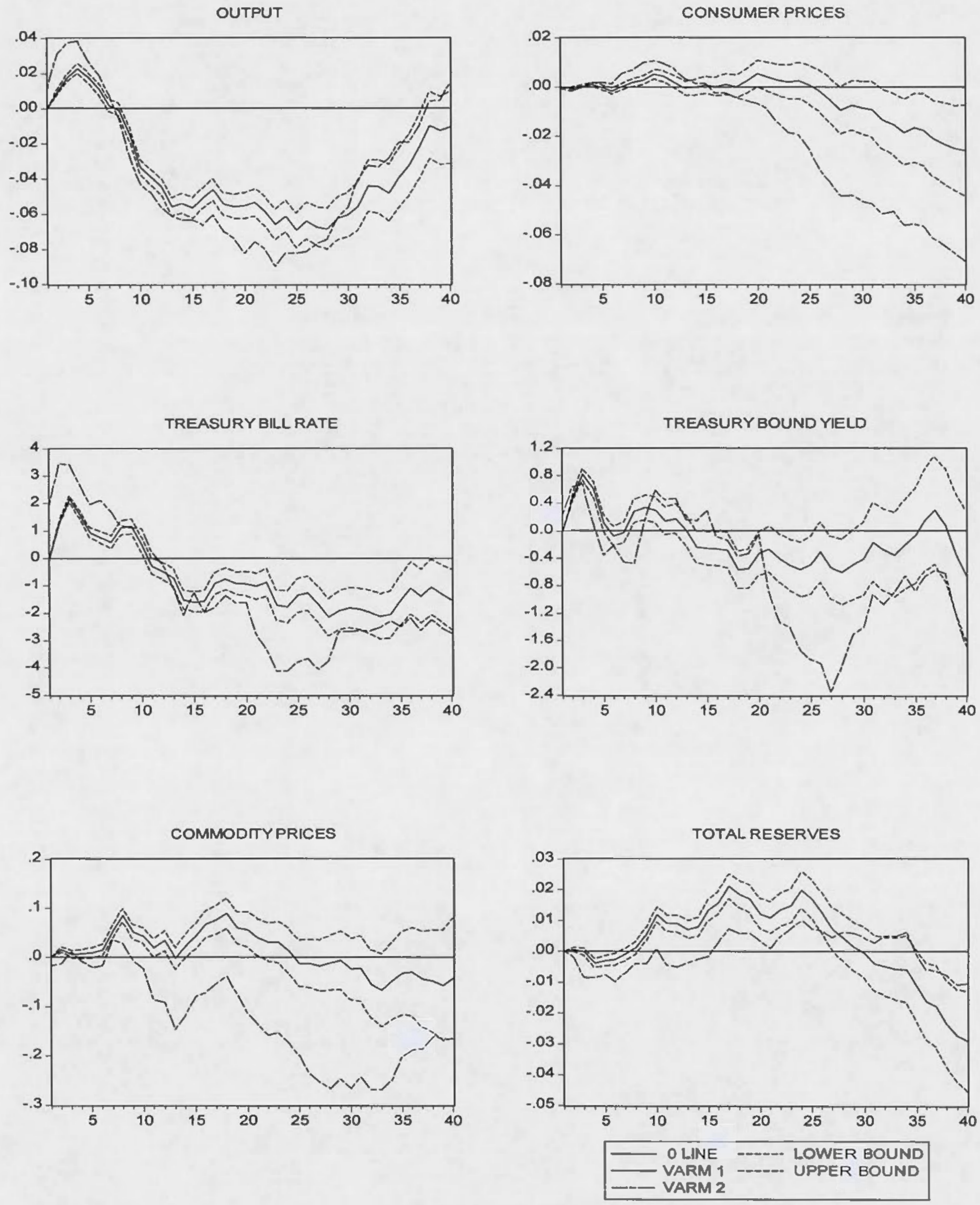


Fig. 2-5: Responses to a Unit Shock on Stock Market Crisis Innovations

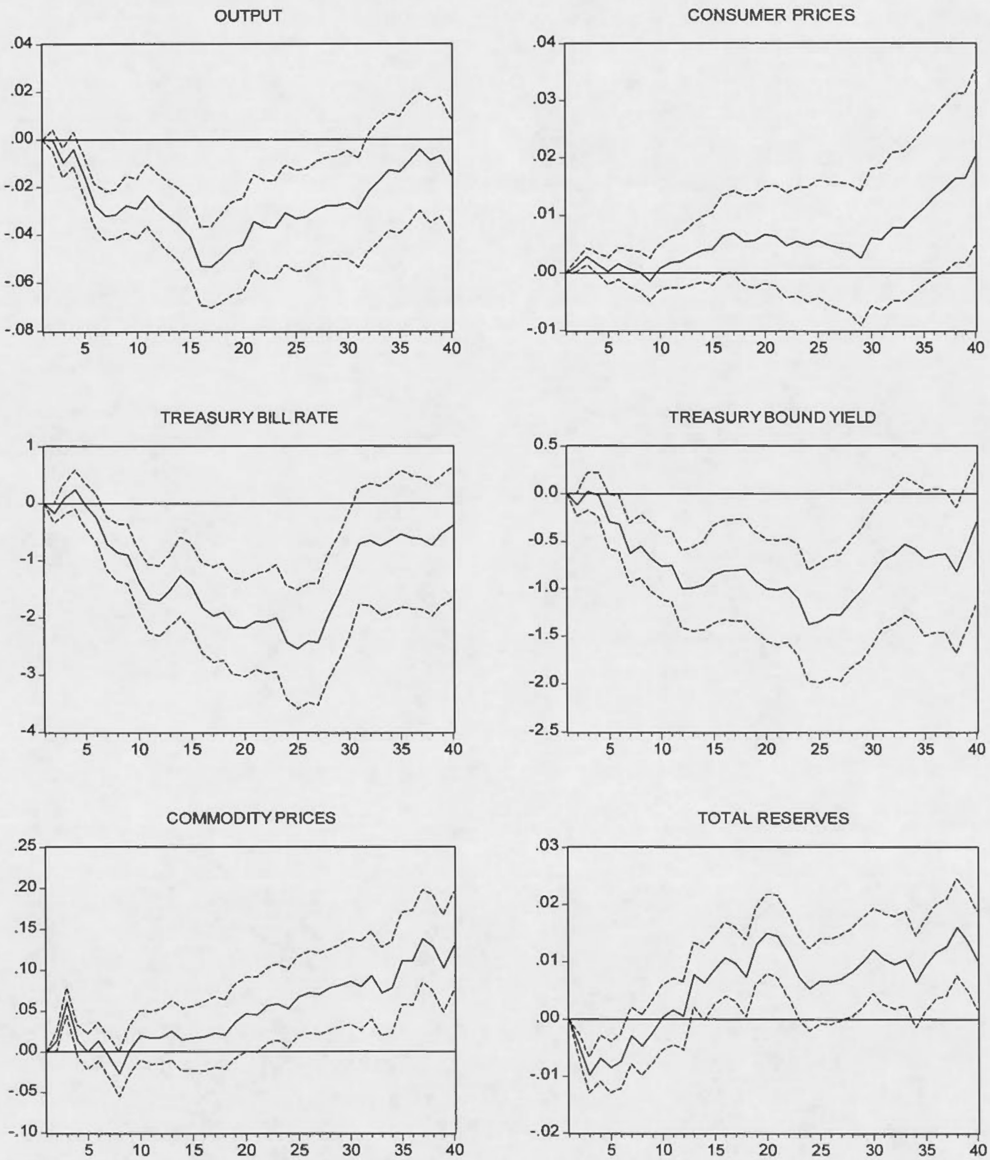


Fig. 2-6: Responses to a Unit Shock on Monetary Policy Innovations

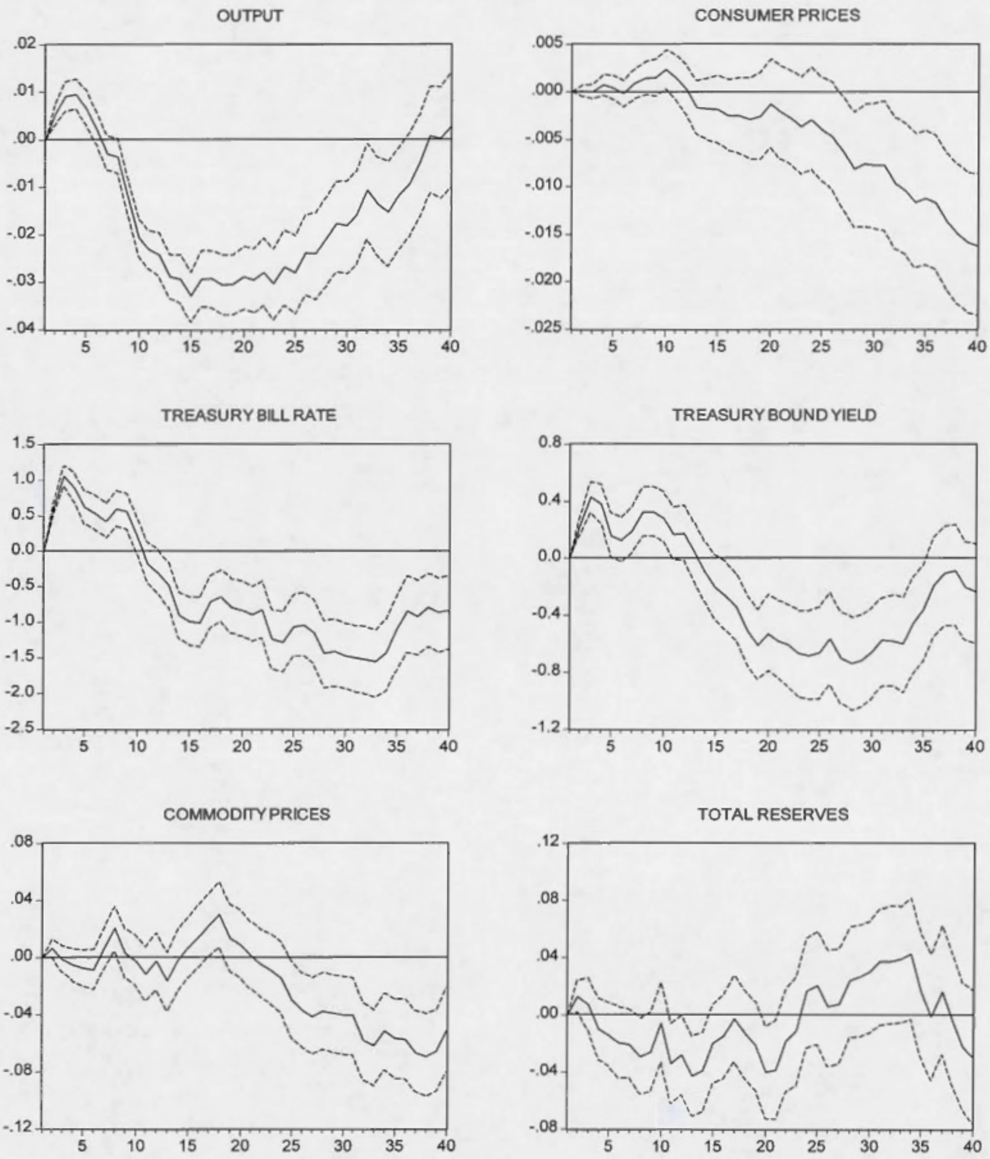


Fig. 2-7: Responses to a Unit Shock on Stock Market Crisis Dummy (Dummy Variable Treated as Exogenous)

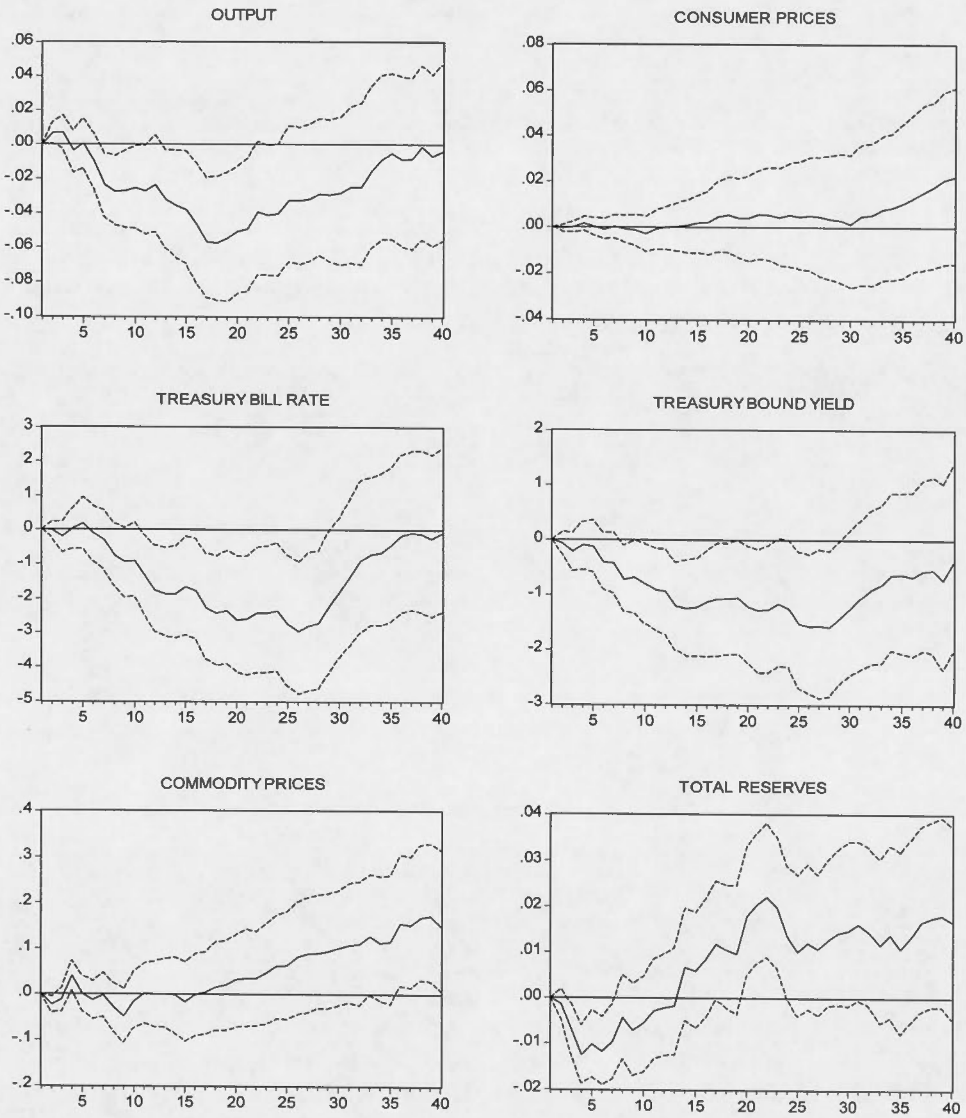


Fig. 2-8: Responses to a Unit Shock on Monetary Policy Variable (Monetary Variable Treated as Exogenous)

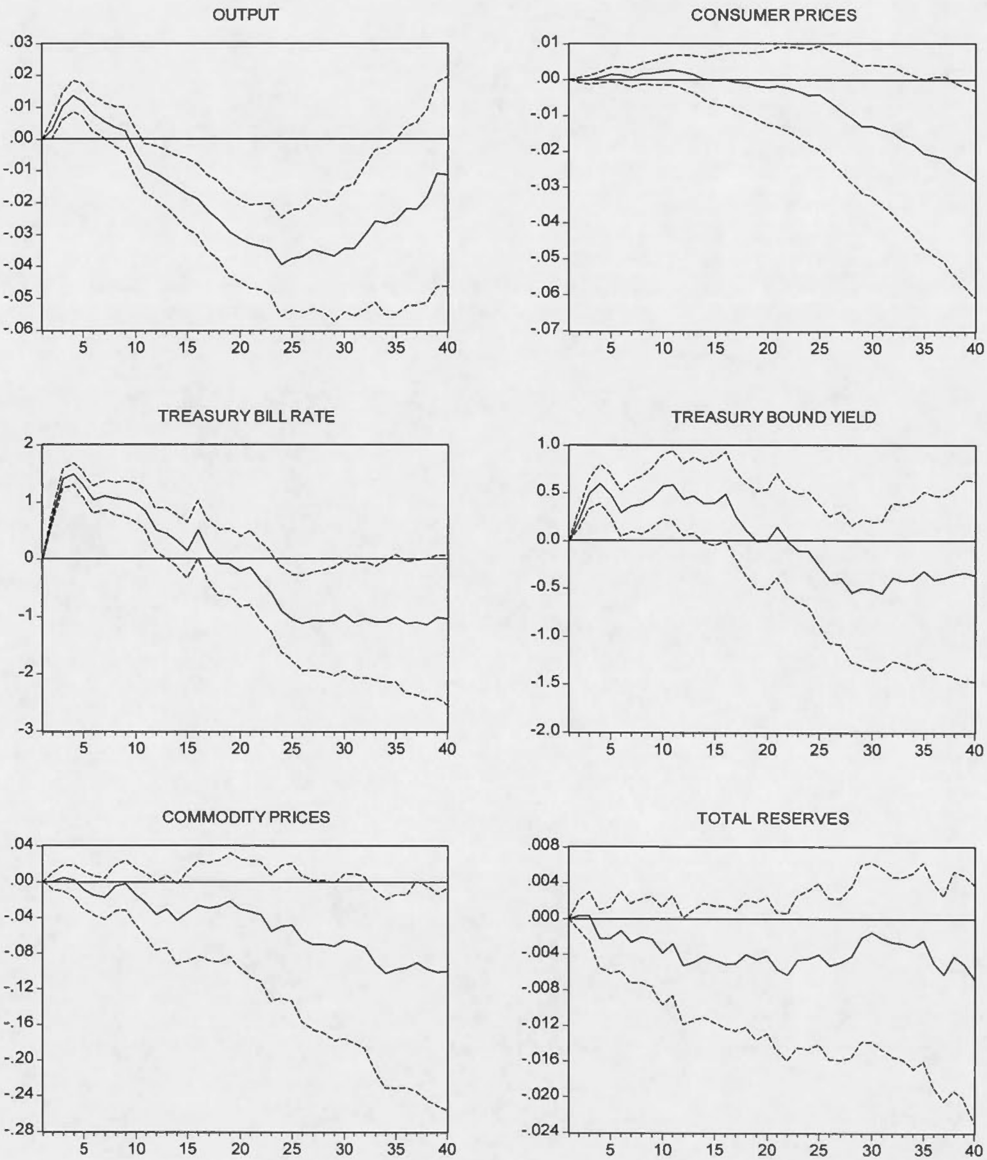


Fig. 2-9: Responses to a Unit Shock on Stock Market Crisis Dummy (Financial VAR with Other Exogenous Shocks)

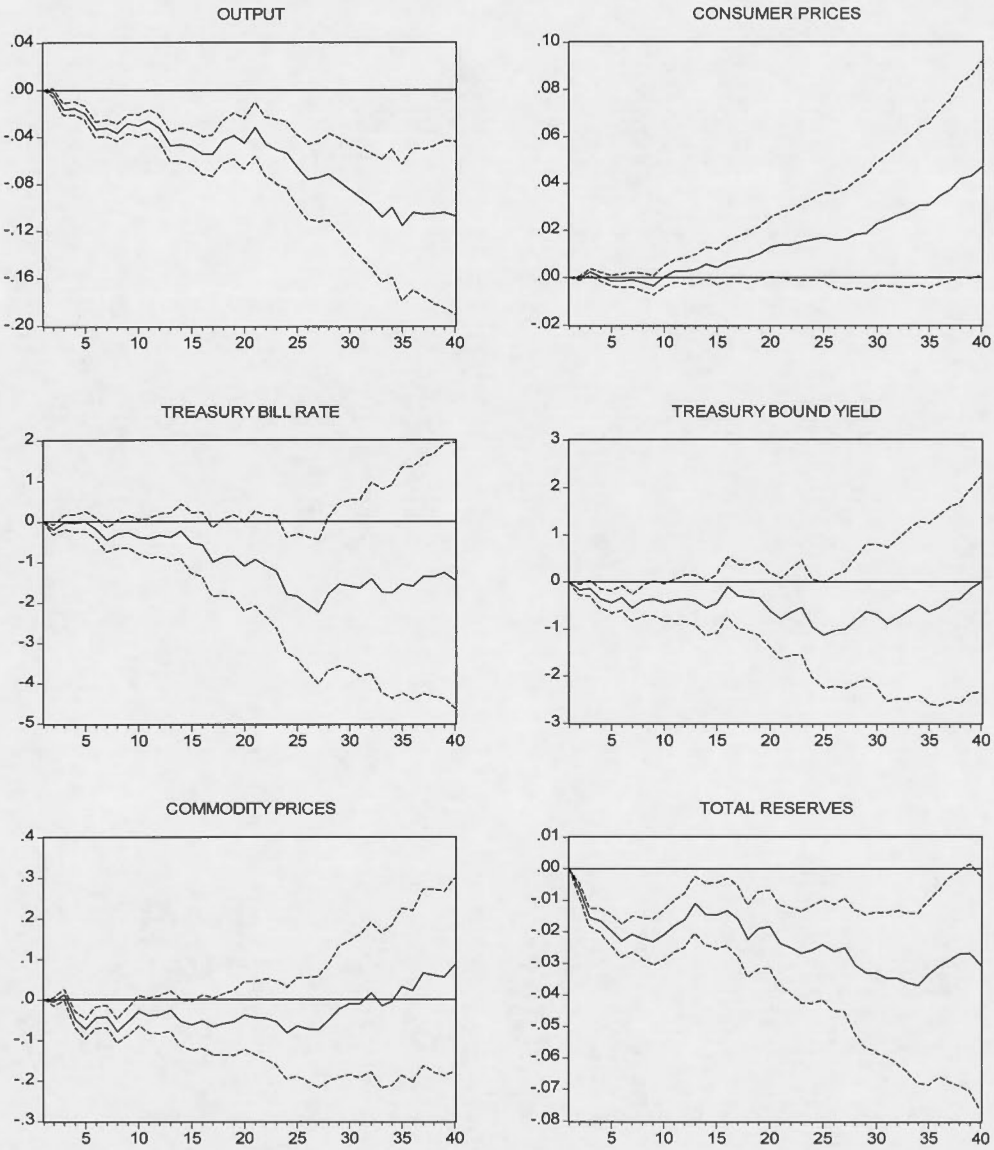


Fig. 2-10: Responses to a Unit Shock on Stock Market Crisis Dummy (Financial VAR with Hamilton Oil Price Exogenous Shocks)

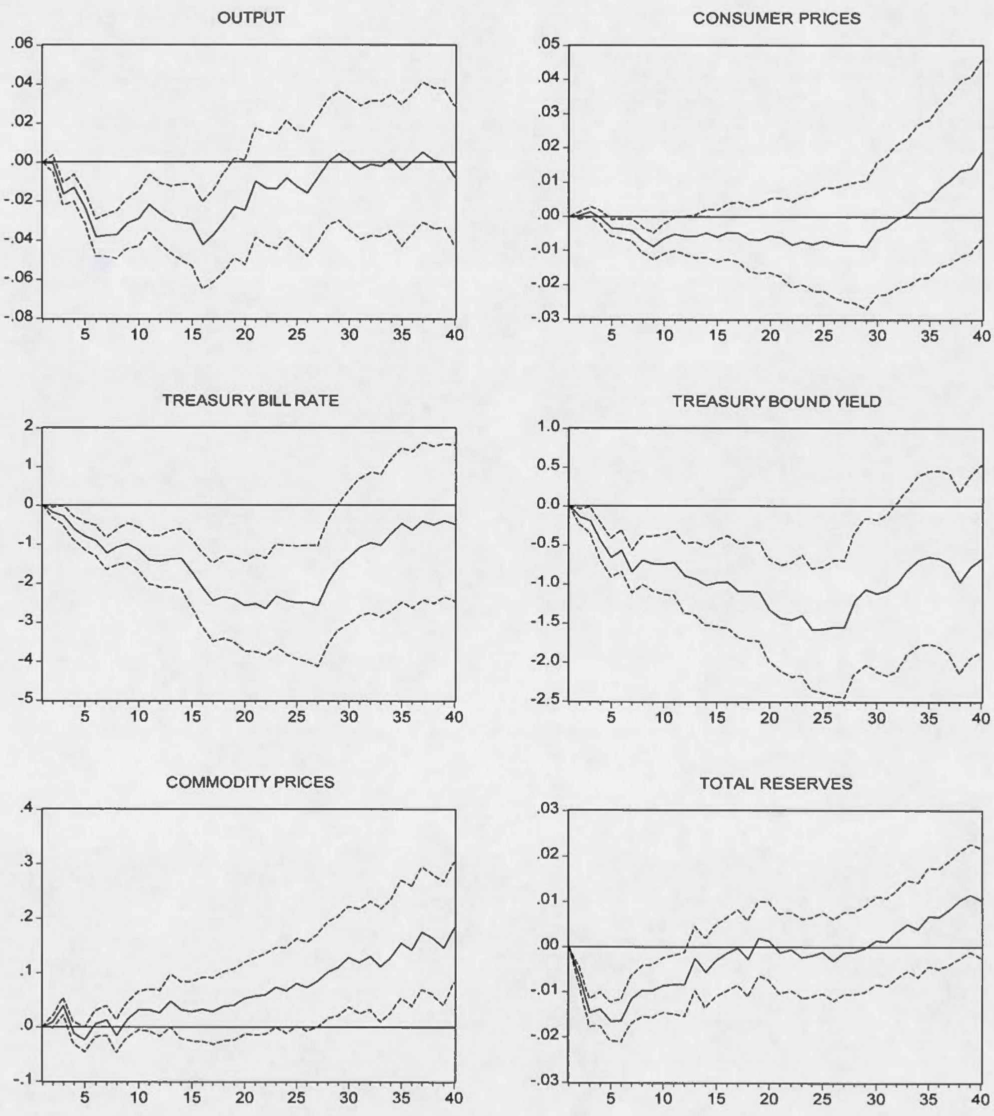


Fig. 2-11: Responses to a Unit Shock on Monetary Policy Variable (Monetary VAR with Other Exogenous Shocks)

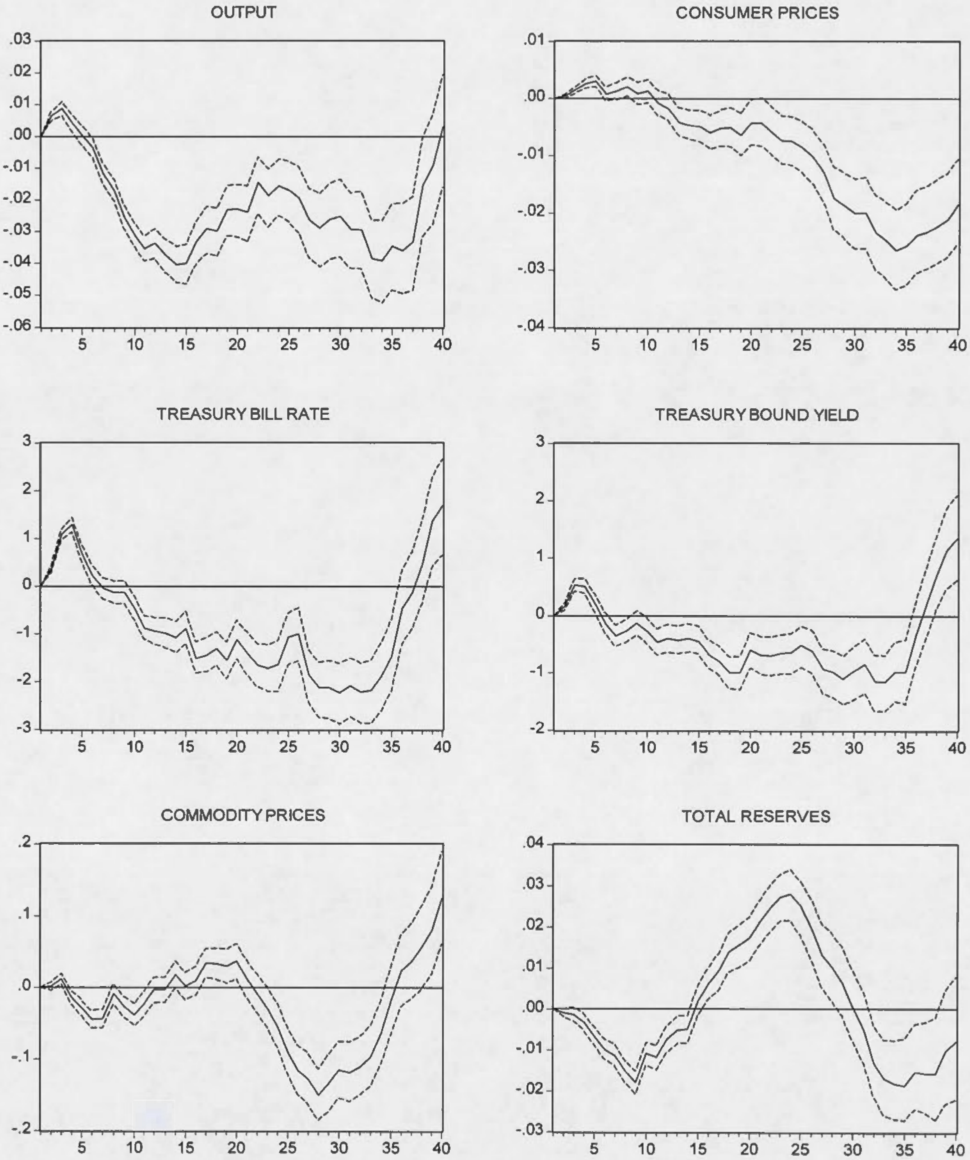


Fig. 2-12: Responses to a Unit Shock on Monetary Policy Variable (Monetary VAR with Hamilton Oil Price Exogenous Shocks)

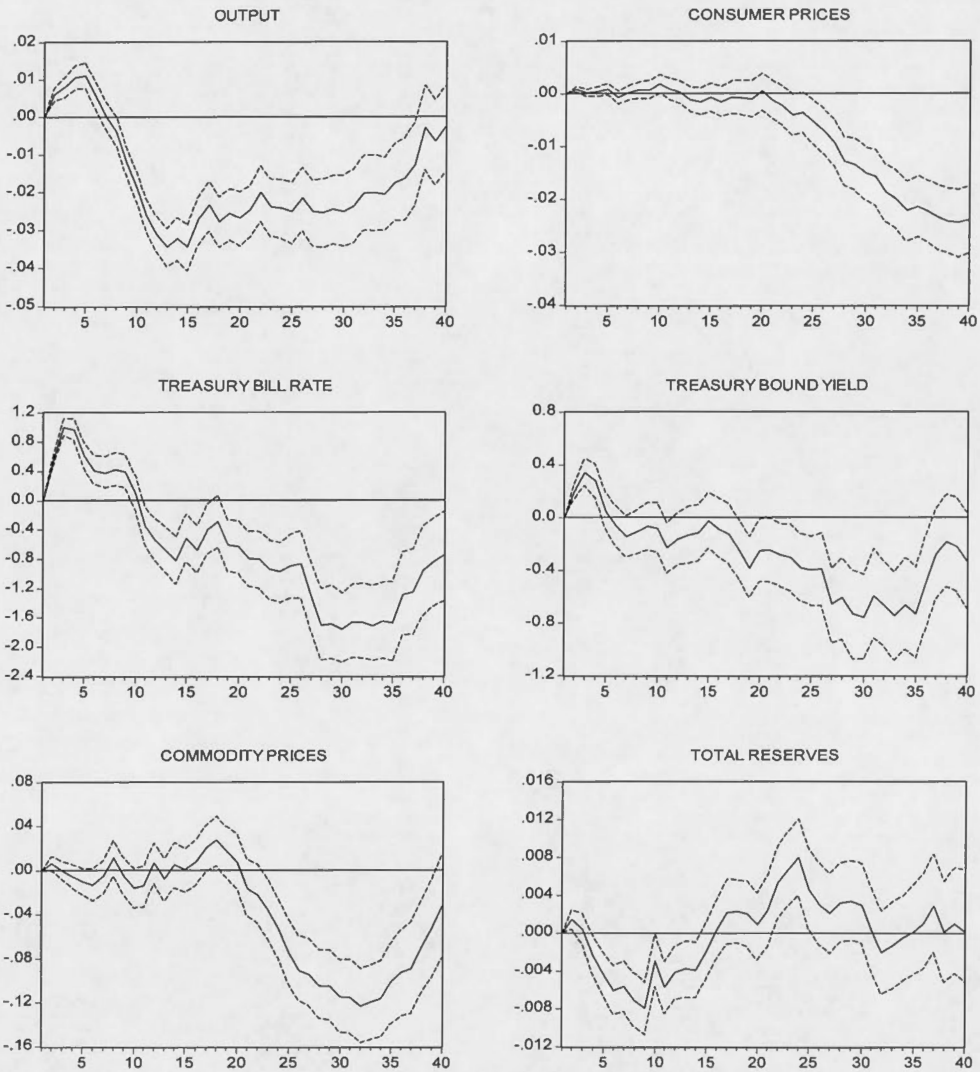
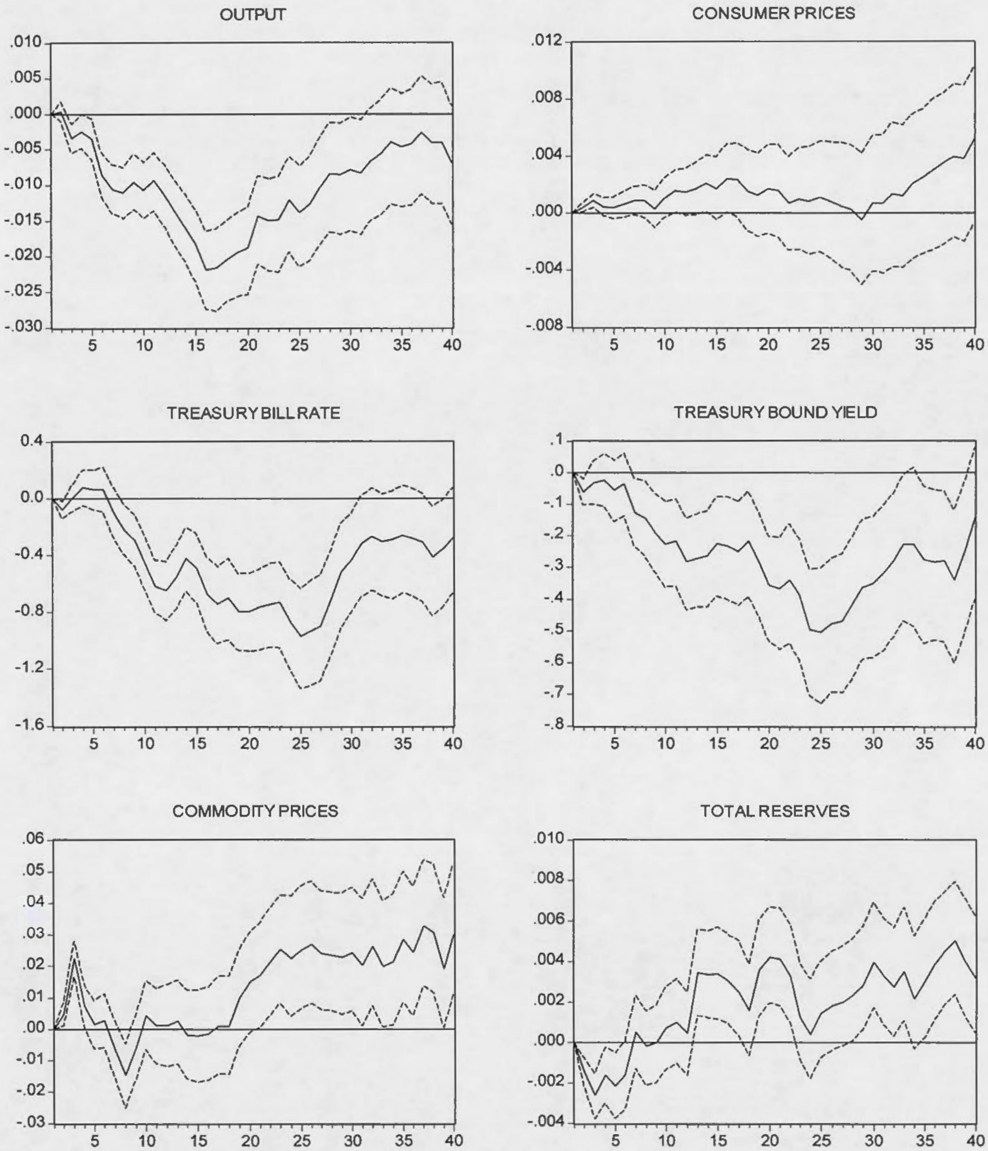


Fig. 2-13: Responses to a Unit Shock on Weighted Stock Market Crisis Variable Innovations (Extended Financial VAR)



CHAPITRE III

HYBRID INFLATION-PRICE-LEVEL TARGETING IN SMALL-OPEN-ECONOMY NEW-KEYNESIAN FRAMEWORK

3.1 Introduction

Throughout the last decade inflation targeting has been widely adopted as a framework for monetary policy. Indeed, several industrialized countries have formally or informally adopted inflation targeting (hereafter, IT), and thus far most of them appear to be enjoying good inflation performance,[1] price stability and satisfactory real growth records.[2]

In contrast, 'conventional wisdom' has been skeptical of price-level targeting (hereafter, PT). The main argument against PT is that it induces both higher short-run inflation and also output variability than does IT (see Fischer, 1994, Haldane and Salmon, 1995). However, Dittmar et al. (1999) and Svensson (1999) argue that PT has some advantages over IT, since with PT inflation variability becomes lower, assuming that output persistence is at least moderate.[3] The controversy mainly concerns the definition of price stability and more particularly how price stability can be maintained in practice. For instance, the monetary authorities should choose paths for either price

[1]A survey of literature on the economic performance of inflation-targeting countries is presented in Svensson (1995) Haldane (1995) and Bernanke et al. (1999).

[2]Canada, Australia, New Zealand, Sweden, the United Kingdom (UK) and other industrialized countries adopted IT regime.

[3]Svensson (1999) and Vestin (2000) argue that price-level targeting yields better output-inflation variability trade-off and price stability than does inflation targeting.

level or for the inflation rate, allowing in the latter case for a base drift in price level.[4]

More recently, Nessen (2002) and Nessen and Vestin (2000) suggest that the central bank should target an average inflation over several periods. Batini and Yates (2003), Cecchetti and Kim (2003) and Kobayashi (2004) investigate another novel proposal that combines IT and PT in a mixed regime, called hybrid inflation/price-level targeting (hereafter, HT). In this proposal inflation volatility becomes lower when compared to PT and IT regimes. Indeed, Batini and Yates (2003) introduce a new perspective on the analysis of price-level and inflation targets by considering a hybrid target, which is a weighted average of an inflation target and a price-level target. They did not, however, use a utility-based welfare loss function as an evaluation criterion. In their analysis of price-level versus inflation targeting under different model specifications, policy rules, and loss functions of the central bank, Batini and Yates (2003) find that the more forward-looking the model, the less noticeable the difference between the reaction functions of inflation and price-level targeting which make the performance of such rules highly dependent on the degree of forward-looking behavior. Using Fuhrer and Moore (1995)'s model to explore the implications of these regimes for the United Kingdom, Batini and Yates (2003) examine both a set of simple rules feeding back from alternative combinations of price level and inflation deviations from target and a set of optimal control rules obtained under the assumption that policy makers minimize a loss function which penalizes a mixed price level/inflation target.[5]

Despite this thriving theoretical literature however, little work has been done to direct evaluate this kind of regime (HT) in open economy modeling cases. An analysis of HT in a small open economy environment is relevant, especially given IT and PT regime shortcomings, as well as the implications of this policy's weakness for central banks. We then attempt to investigate this targeting type in a small open economy

[4]The first known example of an implicit target for price stability was in terms of price level targeting, as adopted by Sweden in the 1930s (see Berg and Jonung, 1999).

[5]Batini and Yates (2003) explored the implications of the HT regime using a reduced-form of the Fuhrer and Moore (1995) model which is not built on microfoundations as compelling as the Calvo model. Like the original Taylor model, the Fuhrer-Moore model is based on some arbitrary but superficially plausible assumptions about the form of labor contracts (Mankiw, 2001).

model, calibrated to the salient features of the Canadian economy.

Our work departs from the above mentioned literature in at least two dimensions along which we extend the work of Batini and Yates (2003) and Kobayashi (2004). First, we consider the New-Keynesian framework rather than the New-Classical environment. Second, we apply welfare analysis to the hybrid monetary policy. We do discuss the potential of this features in detail later on in this chapter.

The small open economy version implies that foreign variables may be included in each equation of the model, and that the treatment of foreign sector variables is different from that used for the closed-economy version. These differences may result in contrasting policy advice or may confirm results obtained in the literature for the HT regime. Moreover, analyzing the small open economy takes into consideration the possibility that international trade and financial assets would affect the evolution of the domestic economy. Thus, foreign shocks such as terms of trade can alter domestic business cycle fluctuations, giving rise to many more dynamics within the model, which may lead the monetary authority to explicitly take these kinds of fluctuations into account (Lubik and Schorfheide, 2003). Further, the recent development in the New Open Economy Macroeconomics originated by Obstfeld and Rogof (1995) leads to a wealth of literature in which micro-founded and optimization-based models are used for policy analysis in the open economy.[6] It highlights the role of the terms of trade in the transmission of business cycles (see Corsetti and Pesenti, 2001).

In line with previous research on monetary policy analysis, we adopt the New-Keynesian framework, a model that many macroeconomic studies have indeed frequently employed.[7] The most important feature of this model is the appearance of terms that reflect the forward-looking behavior of representative agents. This leads for example to a stabilization bias problem that occurs if monetary authorities apply discretionary monetary policy (Clarida et al., 2000). Most of the literature to date uses the new

[6]See Lane (2001) for a survey.

[7]See for example McCallum and Nelson (2000), Clarida et al. (2000), Ball (1999) and Svensson (2000) for a discussion of these kinds of models.

classical model to assess the property of the HT regime and confirms its advantages (Kobayashi, 2004). However, the use of New-Keynesian models in analyzing the HT regime is only in its first stages.[8] In this chapter we attempt to investigate this framework and try to provide evidence that will assist in discriminating between hybrid regimes and other kinds of monetary policy targeting.

Galí and Monacelli (2004)[9] consider a small open economy version of the Calvo sticky price model and show how the equilibrium dynamics can be reduced to a simple representation in domestic inflation and output gap. The model used here further explores this avenue and extends Galí and Monacelli's (2004) framework to account for HT targeting. We use the resulting setting to analyze the macroeconomic implications of three alternative rule-based policy regimes for the small open economy : CPI-inflation based Taylor rule, price level based Taylor rule, and a hybrid inflation/price level based rule.

In our empirical work,[10] we use the New Keynesian framework in a calibrated DSGE model, applying the hybrid monetary policy rule. We calibrate key parameters to match some broad characteristics of the Canadian data. Since analytical solutions are often not available for this regime and empirical literature has not reached a consensus about key parameters, we must then rely on a calibrated model. Subsequently, we conduct a welfare analysis between the various monetary policy regimes considered in this study and compare their impulse response functions.

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[8]Dittmar et al. (1999) Cecchetti and Kim (2003) and Kobayashi (2004) analyzed the Hybrid regime using a model similar to Svensson's (1999) model. Batini and Yates (2003) explored the implications of this regime using the Fuhrer and Moore (1995) model.

[9]The authors develop a tractable optimizing model of a small open economy with staggered price setting à la Calvo to analyze three interest rate rule : domestic inflation-based Taylor rule, CPI-based Taylor rule, and an exchange rate peg.

[10]Different approaches have been adopted by macroeconomists in analyzing DSGE models. Some standard procedures are applied to estimate DSGE models using Maximum Likelihood (ML), Generalized Method of Moments (GMM), Simulated Method of Moments (SMM), the Indirect Inference procedure proposed by Smith (1993) and finally the Bayesian techniques. Most of these modeling techniques have to deal with potential model misspecification and identification problems. Taking the misspecification of those models into consideration, many authors use the calibration approach. Along the lines of that used by Kydland and Prescott (1982), this approach is by far the most common approach found in the literature for examining the empirical properties of DSGE models (An and Schorfheide, 2005).

Our results are consistent with the fact that hybrid inflation/price-level targeting performs well and provides an alternative method for conducting successful monetary policy in the case of a small open economy, without having to worry about the shortcomings of the other monetary policy regimes considered in this work. This is more likely to be the case if the small open economy considered in this work follows monetary policies that allow for some temporary base drift in prices (HT targeting).

The chapter proceeds in the following manner. Section 3.2 sketches the model's derivation as implied by the microfoundations presented by Galí and Monacelli (2004). Section 3.3 provides details on the quantitative methodology and discusses the results. Section 3.4 introduces welfare analysis and provides some results. Section 3.5 presents the concluding remarks.

3.2 The Model

We construct a model that is a variant of a dynamic New-Keynesian model applied to the small open economy, following Clarida et al. (2002) and Galí and Monacelli (2004).

The model has three sectors : 1) a continuum of profit maximizing monopolistically competitive firms (owned by consumers who include its shares in their portfolios) operating a constant returns to scale technology and making staggered price decisions in the spirit of Calvo (1983) ; 2) an infinitely-lived representative household maximizes a utility function defined over a composite consumption good and labor supply ; 3) a central bank sets the monetary policy through an interest rule that targets both the price level and the inflation rate in a hybrid formula.

3.2.1 Firms' Problem

The production function for a typical home economy firm i that produces a differentiated good is as follows :

$$Y_t(i) = A_t N_t(i), \tag{3.1}$$

all $i \in [0, 1]$, $Y_t(i)$ and $N_t(i)$ are the firm i's specific output and labor input, respectively. A_t is a total factor productivity term that follows an $AR(1)$ process (in log deviation), i.e.

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_{a,t},$$

where $\varepsilon_{a,t}$ is a white noise with mean 0 and variance σ_ε^2.

The cost minimization problem leads to express real marginal cost $\widehat{mc}_t$ -which is common across domestic firms, in terms of home prices :

$$\widehat{mc}_t = -\nu + \hat{w}_t - \hat{p}_{H,t} - \hat{a}_t, \tag{3.2}$$

where $\nu = -\log(1-\tau)$, τ is an employment subsidy,[11] $\hat{p}_{H,t}$ and $\hat{w}_t$ stand for the deviations of domestic price and wage rate from their steady state values, respectively.

Let Y_t define the aggregate index for domestic output and N_t the aggregate employment. Y_t and N_t can be expressed in terms of an individual firm's output as follows

$$Y_t = [\int_0^1 Y_t(i)^{\frac{\xi-1}{\xi}} di]^{\frac{\xi}{\xi-1}},$$

$$N_t = \int_0^1 N_t(i)\ di = \int_0^1 \frac{Y_t(i)}{A_t}\ di,$$

where $\xi > 1$ is the elasticity of substitution among goods within each category. Moreover, defining $Z_t = \int_0^1 \frac{Y_t(i)}{Y_t} di$ yields

$$N_t = \frac{Y_t Z_t}{A_t}.$$

In loglinear form (up to a first order approximation) aggregate output reduces to

$$\hat{y}_t = \hat{a}_t + \hat{n}_t, \tag{3.3}$$

where the variables $\hat{y}_t, \hat{a}_t$ and $\hat{n}_t$ represent the deviations of output, total factor productivity and employment from a symmetric steady state.

Price Setting

Price setting behavior follows Calvo (1983) and Yun (1996) in that only a fraction $(1-\psi)$ of firms adjust their price each period, while a fraction ψ of randomly selected firms keep their price unchanged. This leads to a forward-looking pricing decision.

We follow Galí and Monacelli (2004) to determine the new price-setting strategy.[12] Let $P^n_{H,t}$ be the price set by a firm i adjusting its price in period t and facing a probability

[11]The employment subsidy exactly offsets the combined effects of the firm's market power and the terms of trade distortions in the steady state. In this case there is only one effective distortion left in the small open economy model, namely sticky prices.

[12]See Appendix 2 in Galí and Monacelli (2004) for more details.

ψ^k of keeping its price unchanged for k periods (for k=0,1,2,...). The new price must satisfy the following equation

$$P^n_{H,t} = \mu + (1-\beta\psi)\sum_{k=0}^{\infty}(\beta\psi)^k E_t\{mc_{t+k} + P_{H,t+k}\}, \tag{3.4}$$

where μ is the steady state markup.[13] The dynamic of the domestic price index is then given by

$$P_{H,t} = [\psi P^{1-\xi}_{H,t-1} + (1-\psi)(P^n_{H,t})^{1-\xi})]^{\frac{1}{1-\xi}} \tag{3.5}$$

which can be loglinearized to obtain an expression for the domestic inflation as follows

$$\hat{\pi}_{H,t} = (1-\psi)(\hat{p}^n_{H,t} - \hat{p}_{H,t-1}). \tag{3.6}$$

Combining (3.6) with the differentiated version of (3.5) yields the following aggregate supply equation

$$\hat{\pi}_{H,t} = \beta E_t\{\hat{\pi}_{H,t+1}\} + \kappa\widehat{mc}_t \tag{3.7}$$

where $\kappa = (1-\beta\psi)(1-\psi)/\psi$ and $\widehat{mc}_t$ represents the log-deviation of the real marginal cost.

Under the assumption that the degree of price stickiness is identical across economies (small open economy and the rest of the world), the firms in the rest of the world (ROW) face the same price setting problem.

[13]The forward-looking pricing decision is related to the fact that firms that adjust their price in any period do so for a random number of periods. The price is then set as a markup over the average of expected future marginal costs.

3.2.2 Households

Our small open economy is inhabited by a continuum of infinitely-lived households where the representative household seeks to maximize the following expected utility

$$E_t \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \tag{3.8}$$

where N_t is hours worked and C_t is a composite consumption index defined by

$$C_t = [(1-\alpha)^{\frac{1}{\theta}} (C_{H,t})^{\frac{\theta-1}{\theta}} + \alpha^{\frac{1}{\theta}} \ (C_{F,t})^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}}. \tag{3.9}$$

The elasticity of substitution between the indices of home and foreign goods is given by $\theta > 0$. $C_{H,t}$ is the consumption index of j domestic goods defined by the CES aggregator

$$C_{H,t} = [\int_0^1 (C_{H,t}(j))^{\frac{\xi-1}{\xi}} dj]^{\frac{\xi}{\xi-1}}.$$

Likewise, $C_{F,t}$ is the index of imported goods given by

$$C_{F,t} = [\int_0^1 (C_{F,t}(j))^{\frac{\xi-1}{\xi}} dj]^{\frac{\xi}{\xi-1}}$$

where the elasticity of substitution among goods within the two indices ξ is greater than *one*.

Maximization of the expected utility is subject to the sequence of budget constraints of the form

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj + \int_0^1 P_{F,t}(j) C_{F,t}(j) dj + E_t\{O_{t,t+1} D_{t+1}\} \leqslant D_t + W_t N_t + T_t, \tag{3.10}$$

where $P_{H,t}(j)$ is the price of the domestic good j and $P_{F,t}(j)$ is the price of imported good j expressed in home currency. D_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t (including firms' share), W_t is the nominal wage rate and T_t is lump-sum transfers/taxes. $O_{t,t+1}$ is the stochastic discount factor for one-period-ahead nominal payoffs relevant to the domestic household.

It can be shown that the demand functions for the domestic and foreign goods satisfy

$$C_{H,t}(j) = (\frac{P_{H,t}(j)}{P_{H,t}})^{-\xi}\, C_{H,t}, \tag{3.11}$$

$$C_{F,t}(j) = (\frac{P_{F,t}(j)}{P_{F,t}})^{-\xi}\, C_{F,t}. \tag{3.12}$$

Note that the above functions define the quantities consumed for each type of good, where $P_{H,t}$ and $P_{F,t}$ are the domestic and foreign price indices expressed in domestic currency. $P_{H,t}$ and $P_{F,t}$ are then given by the following expressions

$$P_{H,t} = [\int_0^1 (P_{H,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}}, \tag{3.13}$$

$$P_{F,t} = [\int_0^1 (P_{F,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}}. \tag{3.14}$$

Combining (3.11)-(3.14) to obtain

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj = P_{H,t} C_{H,t},$$

$$\int_0^1 P_{F,t}(j) C_{F,t}(j) dj = P_{F,t} C_{F,t}.$$

Similarly, it can be show that the optimal allocations between domestic and imported goods are given by the following relations

$$C_{H,t} = (1-\alpha)(\frac{P_{H,t}}{P_t})^{-\theta} C_t,$$

$$C_{F,t} = \alpha(\frac{P_{F,t}}{P_t})^{-\theta} C_t.$$

The consumer price index is then,

$$P_t \equiv [(1-\alpha)(P_{H,t})^{1-\theta} + \alpha(P_{F,t})^{1-\theta}]^{\frac{1}{1-\theta}},$$

the following loglinearized form obtains

$$\hat{p}_t = (1-\alpha)\ \hat{p}_{H,t} + \alpha\ \hat{p}_{F,t}.$$

We can then compute the total consumption expenditures by domestic households as follows

$$P_{H,t}\ C_{H,t} + P_{F,t}\ C_{F,t} = P_t\ C_t. \tag{3.15}$$

Substituting (3.15) back into (3.10) yields

$$P_t\ C_t + E_t\{O_{t,t+1}D_{t+1}\} \leqslant D_t + W_t N_t + T_t. \tag{3.16}$$

We then introduce the following functional form for the utility function :

$$U(C_t, N_t) = \frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\phi}}{1+\phi}.$$

The Lagrangian expression for this problem is then given by

$$\underset{C_t,N_t,D_{t+1}}{Max}\ E_0\{\sum_{t=0}^{\infty}\beta^t[\frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\phi}}{1+\phi} + \lambda_t(D_t + W_t N_t + T_t - P_t C_t - E_t(O_{t,t+1}D_{t+1}))]\}. \tag{3.17}$$

The intratemporal optimality condition follows from the household problem

$$C_t^{\sigma} N_t^{\phi} = \frac{W_t}{P_t}. \tag{3.18}$$

On the other hand, intertemporal optimization (for all states and dates) implies the following Euler equation with regards to consumption

$$O_{t,t+1} = \beta(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+1}}). \tag{3.19}$$

Let $R_t = 1/E_t O_{t,t+1}$ define the gross return on the riskless period discount bond paying off one unit of domestic currency in $t+1$. Equation (3.19) can easily be rewritten as a standard Euler equation

$$\beta R_t E_t\{(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+1}})\} = 1 \tag{3.20}$$

which in loglinearized form yields,

$$\hat{c}_t = E_t\hat{c}_{t+1} - \frac{1}{\sigma}(r_t - E_t\hat{\pi}_{t+1} - \rho)$$

where $\rho \equiv -\log\beta$ is the time discount factor.

In the rest of the world a representative household faces a problem similar to the one outlined above. We assume here that relative to the ROW economy the size of the small open economy is negligible.[14]

Some Identities

We assume that the law of one price holds for all goods (including imported goods) at all times implying that

$$P_{F,t}(j) = \epsilon_t P^F_{F,t}(j) \text{ for all } j \in [0,1], \tag{3.21}$$

where ϵ_t is the bilateral nominal exchange rate,[15] $P^F_{F,t}(j)$ is the price of the good (j) produced in a foreign country in terms of the foreign currency.

[14]This assumption allows us to treat the ROW economy as a closed economy.
[15]The price of foreign country currency in terms of domestic currency.

Substituting (3.14) into (3.21) yields the following expression for the foreign price index

$$P_{F,t} = \epsilon_t [\int_0^1 (P^F_{F,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}}.$$

Similarly, if we define the foreign price index as

$$P_t^* = [\int_0^1 (P^F_{F,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}},$$

we can write the relation between the home price of imported goods and the foreign price index in loglinearized form around a steady state as

$$\hat{p}_{F,t} = \hat{e}_t + \hat{p}_t^*. \tag{3.22}$$

In addition, using the term of trade definition $S_t = \epsilon_t P_t^* / P_{H,t}$, and loglinearizing around a symmetric steady state, yields

$$\hat{s}_t = \hat{e}_t + \hat{p}_t^* - \hat{p}_{H,t}. \tag{3.23}$$

Since by definition the real exchange rate (in loglinearized form) is given by

$$\hat{q}_t = \hat{e}_t + \hat{p}_t^* - \hat{p}_t,$$

substituting into equation (3.23) yields the following relation between the real exchange rate and the terms of trade given the price levels :

$$\hat{q}_t = \hat{s}_t + \hat{p}_{H,t} - \hat{p}_t. \tag{3.24}$$

On the other hand, using the definition of the price indices it can be shown that

$$\frac{P}{P_H}\hat{p}_t - \frac{P}{P_H}\hat{p}_{H,t} = [(1-\alpha) + \alpha(S)^{1-\theta}]^{\frac{1}{1-\theta}} S^{1-\theta} \alpha \hat{s}_t. \tag{3.25}$$

Furthermore, assuming that purchasing power parity (PPP) holds in the steady state, i.e.,

$$S = \frac{P_F}{P_H} = 1, \tag{3.26}$$

and combining (3.23), (3.25) and (3.26), we can write the relation between the domestic price level and the CPI as follows,

$$\hat{p}_t - \hat{p}_{H,t} = \alpha \hat{s}_t. \tag{3.27}$$

As a result, domestic inflation relates to CPI inflation according to

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \alpha \Delta \hat{s}_t. \tag{3.28}$$

Substituting (3.27) back into (3.24) yields an expression for the real exchange rate as a function of terms of trade, i.e.,

$$\hat{q}_t = (1 - \alpha)\hat{s}_t, \tag{3.29}$$

which establishes a relation between real exchange rate and terms of trade, depending on the degree of openness of the SOE.

International Risk Sharing

In our work we assume that there exists in the world a complete securities market so that the Euler equation would also hold for the foreign representative household,[16] i.e.

$$O_{t,t+1} = \beta E_t\{(\frac{C^*_{t+1}}{C^*_t})^{-\sigma}(\frac{P^*_t}{P^*_{t+1}})(\frac{\epsilon_t}{\epsilon_{t+1}})\}. \tag{3.30}$$

[16] In terms of domestic currency.

Hence, combining equation (3.30) with its domestic counterpart, substituting in $Q_t = \epsilon_t P_t^*/P_t$ and rearranging terms yields :

$$C_t = Q_{t+1}^{-\frac{1}{\sigma}} \frac{C_{t+1}}{C_{t+1}^*} C_t^* Q_t^{\frac{1}{\sigma}}. \tag{3.31}$$

Finally, replacing C_{t+1} and C_{t+1}^* with their respective expression yields the optimal allocation for the imported good :

$$C_t^* = \alpha Q_t^{-\theta} C_t. \tag{3.32}$$

Therefore, the relation (3.31) can be rewritten as

$$C_t = \Phi_o C_t^* Q_t^{\frac{1}{\sigma}},$$

where Φ_o depends on initial condition of the country's asset position. If we assume symmetric initial conditions between home and foreign country, with zero foreign asset holdings for the small open economy, without loss of generality we obtain $\Phi_o = 1$ so that the loglinearized form leads to

$$\hat{c}_t = \hat{c}_t^* + \frac{1}{\sigma} \hat{q}_t. \tag{3.33}$$

Substituting (3.29) back into (3.33) then yields

$$\hat{c}_t = \hat{c}_t^* + \frac{1-\alpha}{\sigma} \hat{s}_t. \tag{3.34}$$

which links both consumption variables to the terms of trade.

Uncovered Interest Parity

Under the assumption of complete securities markets , the previous Euler equation also holds for foreign households, i.e.

$$\beta R_t^* E_t\{(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}(\frac{P_t^*}{P_{t+1}^*})\} = 1,$$

or, put another way,

$$R_t^{*-1} = \beta E_t\{(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}(\frac{P_t^*}{P_{t+1}^*})\}. \tag{3.35}$$

Substituting (3.35) back into equation (3.30) yields the price of a riskless bond dominated in foreign currency as

$$R_t^{*-1}\epsilon_t = E_t\{O_{t,t+1}\epsilon_{t+1}\}. \tag{3.36}$$

Since by definition $R_t^{-1} = E_t O_{t,t+1}$, (3.36) implies that

$$E_t\{O_{t,t+1}[R_t - R_t^*(\epsilon_{t+1}/\epsilon_t)]\} = 0. \tag{3.37}$$

The loglinearized form around the steady state gives the asset pricing equation for nominal bounds which implies that the interest rate differential is related to the expected exchange rate depreciation,

$$\hat{r}_t - \hat{r}_t^* = E_t\{\Delta\hat{e}_{t+1}\}, \tag{3.38}$$

where $\hat{e}_t$ is the deviation of the nominal exchange rate from its steady state value.

3.2.3 Monetary Policy

To close the model, we assume that the central bank sets the nominal interest rate following a Taylor-type interest-rate rule. However, money does not appear in either the household utility function or in the budget constraint. Indeed, recent research on monetary policy adopts this modeling strategy (Galí and Monacelli, 2004). In this kind of model money plays the role of an account unit only. Moreover, the influential work by Taylor (1993) uses an interest rate feedback from output and inflation to approximate monetary policy. Recently Woodford (2000) demonstrated that the interest rate rule is consistent with nominal demand determinacy for forward-looking models even when money demand is not present in the model. In addition, in an open economy model the exchange rate is affected by the difference between domestic and foreign nominal interest rates and expected future exchange rates, via an interest parity condition (Svensson, 1998). Moreover, the real exchange rate will affect the relative price between domestic and foreign goods, which in turn will affect both domestic and foreign demand for domestic goods, and hence contribute to movements in CPI inflation. Likewise, the exchange rate affects the domestic currency prices of imported final goods, which are included in the CPI price. In this way, monetary policy can affect both the CPI price and CPI inflation rate. Consequently, analyzing our model we consider a monetary rule that incorporates both the price level and the inflation rate, although the historical rule is rather an inflation-based rule.

As in Taylor (1993, 1996) and Batini and Yates (2003), we assume that the monetary policy follows the generalized Taylor rule of the form

$$\hat{r}_t = E_t\{\hat{\pi}_{t+1}\} + \phi_p(E_t\hat{p}_t - \chi\hat{p}_{t-1}) + \phi_y\bar{x}_t, \tag{3.39}$$

where $\hat{r}_t$ denotes the short-term nominal interest rate and $\hat{\pi}_t$, $\hat{p}_t$ are defined in the same way as above, and $\bar{x}_t$ is the output gap. $\chi \in [0, 1]$ is the parameter that defines the spectrum of targets between price level and inflation targeting. When $\chi = 0$, the policy makers target the price level and when $\chi = 1$, the level of the inflation rate is targeted. For $0 < \chi < 1$ the target is a hybrid regime targeting both price level and inflation rate level.

3.2.4 Equilibrium Determination

Aggregate Demand

World Output and Consumption

Combining the market clearing condition for the ROW economy $\hat{y}_t^* = \hat{c}_t^*$, along with the Euler equation for the foreign household's consumption,

$$\hat{c}_t^* = E_t\hat{c}_{t+1}^* - \frac{1}{\sigma}(r_t^* - E_t\hat{\pi}_{t+1}^* - \rho),$$

leads to a version of the new IS equation in the case of sticky price models

$$\hat{y}_t^* = E_t\hat{y}_{t+1}^* - \frac{1}{\sigma}(r_t^* - E_t\hat{\pi}_{t+1}^* - \rho).$$

This IS equation shows that the foreign output is related negatively to the world interest rate and positively to the expected foreign CPI inflation.

Small Open Economy Output, Consumption and Trade Balance

Market clearing for domestic goods requires that

$$Y_t(i) = C_{H,t}(i) + C_{H,t}^*(i),$$

where $Y_t(i)$, $C_{H,t}(i)$ and $C_{H,t}^*(i)$ are, respectively, the production, home and foreign demand for home produced good i. Moreover based on preference symmetry between the home and the foreign country it can be shown that

$$C_{H,t}^* = \alpha(\frac{P_{H,t}(i)}{P_{H,t}})^{-\xi}(\frac{P_{H,t}}{\epsilon_t P_{F,t}^F})^{-\xi}(\frac{P_{F,t}^F}{P_t^*})^{-\theta}C_t^*. \tag{3.40}$$

Substituting (3.40) back into in the market clearing condition above, we get

$$Y_t(i) = (\frac{P_{H,t}(i)}{P_{H,t}})^{-\xi}\{(1-\alpha)(\frac{P_{H,t}}{P_t})^{-\theta}C_t + \alpha(\frac{P_{H,t}}{\epsilon_t P^F_{F,t}})^{-\xi}(\frac{P^F_{F,t}}{P^*_t})^{-\theta}C^*_t\}$$

for all $i \in [0,1]$ and for all t.

Using the fact that $S_t \equiv \epsilon_t P^F_{F,t}/P_{H,t}$ the aggregate output can be shown to reduce to

$$Y_t = (\frac{P_{H,t}}{P_t})^{-\theta}C_t[(1-\alpha) + \alpha S_t^{\xi-\theta}Q_t^{\theta-\frac{1}{\sigma}}]. \tag{3.41}$$

Log-linearizing (3.41) while making use of $\hat{p}_{H,t} - \hat{p}_t = \alpha\hat{s}_t$ yields

$$\hat{y}_t = \ \hat{c}_t + \alpha\xi\hat{s}_t + \alpha(\theta - \frac{1}{\sigma})\hat{q}_t. \tag{3.42}$$

Equation (3.42) states that the relation between output and consumption in terms of exchange rate and terms of trade variables, is governed by the economy's degree of openness.

Furthermore, notice that using $\hat{q}_t = (1-\alpha)\hat{s}_t$ the expression (3.42) can be rewritten as

$$\hat{y}_t = \ \hat{c}_t + \frac{\alpha\omega}{\sigma}\hat{s}_t, \tag{3.43}$$

where $\omega = \xi\sigma + (\sigma\theta - 1)(1-\alpha)$. Using the fact that

$$\hat{c}_t = \hat{y}^*_t + (\frac{1-\alpha}{\sigma})\hat{s}_t,$$

equation (3.43) becomes

$$\hat{y}_t = y^*_t + \frac{1}{\sigma_\alpha}\ \hat{s}_t \tag{3.44}$$

where $\sigma_\alpha = \sigma/[(1-\alpha) + \alpha\omega]$ and the subscript in σ_α is meant to emphasize the dependence of this parameter on the degree of openness of the economy (α). Finally we can compute a version of the new IS equation for the SOE by combining the Euler equation (3.20) with (3.43), which yields

$$\hat{y}_t = E_t\{\hat{y}_{t+1}\} - \frac{1}{\sigma}(\hat{r}_t - E_t\{\hat{\pi}_{t+1}\} - \rho) - \frac{\alpha\omega}{\sigma}E_t\{\hat{s}_{t+1}\}.$$

This leads to a difference equation for output which is related to the domestic interest rate, world output and domestic inflation

$$\hat{y}_t = E_t\{\hat{y}_{t+1}\} - \frac{1}{\sigma_\alpha}(\hat{r}_t - E_t\{\hat{\pi}_{t+1}\} - \rho) + \alpha(\omega - 1)E_t\{\Delta\hat{y}^*_{t+1}\}. \tag{3.45}$$

This SOE equation is different from its closed economy version because it depends on the small economy's degree of openness and on foreign output[17].

Moreover, net exports (nx) are related to domestic output in terms of steady state output (Y) through the following equation

$$nx_t = (\frac{1}{Y})(Y_t - \frac{P_t}{P_{H,t}}C_t). \tag{3.46}$$

Combining the linearized version of (3.46) with (3.27), (3.34) and (3.43) yields

$$\hat{nx}_t = (1 - \Lambda)(\hat{y}_t - \hat{y}^*_t)$$

where $\Lambda = \sigma_\alpha[(1-\alpha)+\alpha\sigma]/\sigma$. The relationship between the net exports and the output differential is ambiguous and depends on the value of Λ. If $-1 < \Lambda < 1$, a positive output differential generates a trade surplus favorable to the small open economy and with $\Lambda > 1$ or $\Lambda < -1$ the trade surplus is favorable to the foreign country. Following Galí and Monacelli (2004) we need $-1 \leq \Lambda \leq 1$ to satisfy the Marshall-Lerner conditions[18].

[17]It's easy to see that with $\alpha = 0$, we can obtain the closed economy version.

[18]The Marshall-Lerner conditions apply if and only if the sum of the import and export elasticities is greater than one.

Deriving the New Keynesian Phillips Curve (NKPC)

Price stickiness is the main source of nominal rigidity in the model developed above[19]. The model is then consistent with what has been termed the NKPC. Indeed, using equation (3.2) which relates the relation between marginal cost and macro variables it can be shown that

$$\begin{aligned}\widehat{mc}_t &= -\nu + \hat{w}_t - \hat{p}_{H,t} - \hat{a}_t \\ &= -\nu + \phi\hat{y}_t + \sigma\hat{y}_t^* + \hat{s}_t - (1+\phi)\hat{a}_t,\end{aligned}$$

after making use of (3.3) and (3.34). Substituting it in (3.44) this yields

$$\widehat{mc}_t = -\nu + (\sigma_\alpha + \phi)\hat{y}_t + (\sigma - \sigma_\alpha)\hat{y}_t^* - (1+\phi)\hat{a}_t. \tag{3.47}$$

On the other hand we can define the output gap[20] as the difference between the domestic output and 'natural' output as

$$\bar{x}_t = \hat{y}_t - \bar{y}_t, \tag{3.48}$$

where natural output is computed by imposing the restriction : $\widehat{mc}_t = -\mu$ for all t in equation (3.47) and solving for domestic output, i.e.

$$-\mu = -\nu + (\sigma_\alpha + \phi)\bar{y}_t + (\sigma - \sigma_\alpha)\hat{y}_t^* - (1+\phi)\hat{a}_t,$$

[19]The price stickiness is the only source of suboptimality in the equilibrium allocation. Indeed, as shown by Galí and Monacelli (2004), the employment subsidy neutralizes the market power distortion and by not assigning any explicit value to monetary holding balances, the monetary distortion that would pull monetary policy towards the Friedman rule is eliminated.

[20]In our model we have to handle three definitions of output : A measure of output, the natural output (which we get in an economy with no imperfection or nominal rigidity) and finally the output gap which is the difference between the output and the natural output.

which, after some algebraic manipulations, yields the natural output level as

$$\bar{y}_t = \Omega + \Gamma \hat{y}_t^* + \Psi \hat{a}_t, \tag{3.49}$$

where $\Omega = (\nu - \mu)/(\sigma_\alpha + \phi)$, $\Gamma = (\sigma_\alpha - \sigma)/(\sigma_\alpha + \phi)$ and finally $\Psi = (1 + \phi)/(\sigma_\alpha + \phi)$. Equation (3.49) states that the natural output for the small open economy is determined by world output and productivity, as well as domestic markup. In addition we can derive a relationship between real marginal cost and output gap as

$$\widehat{mc}_t = -\nu + (\sigma_\alpha + \phi)\bar{x}_t + (\sigma_\alpha + \phi)(\Omega + \Gamma y_t^* + \Psi \hat{a}_t) + (\sigma - \sigma_\alpha)\hat{y}_t^* - (1 + \phi)\hat{a}_t$$

where natural output has been substituted for its value in (3.49). By rearranging terms we get

$$\widehat{mc}_t = (\sigma_\alpha + \phi)\bar{x}_t. \tag{3.50}$$

Substituting (3.7) into (3.50) yields a NKPC-like equation

$$\hat{\pi}_{H,t} = \beta E_t\{\hat{\pi}_{H,t+1}\} + \delta \bar{x}_t, \tag{3.51}$$

where $\delta = \kappa(\sigma_\alpha + \phi)$. Notice that only the degree of openness (α) affects the small open economy version of the NKPC, and with $\alpha = 0$, we can easily see that the Phillips equation is exactly equivalent to that of the closed economy.

The equilibrium dynamics for the small open economy in terms of output gap and domestic inflation can be completed by writing a version of the IS equation in terms of the output gap. Indeed, by combining (3.45) and (3.49) it can be shown that

$$\bar{x}_t = E_t\{\bar{x}_{t+1}\} - \frac{1}{\sigma_\alpha}(\hat{r}_t - E_t\{\hat{\pi}_{H,t+1}\} - \rho) + \Gamma(\rho_a - 1)\hat{a}_t + \alpha(\Psi + \Theta)E_t\{\hat{y}_{t+1}^*\}, \tag{3.52}$$

where $\Theta = (\omega - 1)$. If we define the natural interest rate as

$$\overline{rr}_t \equiv \rho - \sigma_\alpha \Gamma(\rho_a - 1)\hat{a}_t + \alpha\sigma_\alpha(\Psi + \Theta)E_t\{\hat{y}_{t+1}^*\},$$

where the degree of openness and the expected world output affect the natural rate of interest and then the new IS equation which has the following form

$$\bar{x}_t = E_t\{\bar{x}_{t+1}\} - \frac{1}{\sigma_\alpha}(\hat{r}_t - E_t\{\hat{\pi}_{H,t+1}\} - r\bar{r}_t\ ). \tag{3.53}$$

Equation (3.53) relates the output gap in the forward-looking equation to interest rate, domestic inflation and natural interest rate.

To solve this model we make a loglinear approximation of its equilibrium conditions around a balanced-trade zero-inflation steady state.[21] The model's dynamic properties depend in a crucial manner on the monetary policy used. Indeed, with the Taylor rule where the χ parameter takes the value 1, the persistent inflation response to a technology shock implies that this shock will have a permanent effect on price level, which will then have a unit root, mirrored by a unit root in the nominal exchange rate. In this case, and following Galí and Monacelli (2004) when targeting inflation rate, the monetary authority seeks to stabilize CPI inflation. Such a policy only requires that we set

$$\hat{r}_t - E_t\{\hat{\pi}_{t+1}\} = \phi_p(E_t\hat{\pi}_t) + \phi_y\bar{x}_t,$$

for all t. Moreover, and following Woodford (1999) and Bullard and Mitra (2003), our analysis focuses on the case where ϕ_p and ϕ_y have non negative values. Thus, the necessary and sufficient condition for a stable allocation path[22] is given by

$$\delta(\phi_p - 1) + (1-\beta)\phi_y \neq 0. \tag{3.54}$$

Furthermore, we assume that the foreign country pursues an optimal policy, implying a constant foreign price level at equilibrium.[23] The model's dynamics can be stable in this case, even with non stationary prices. Otherwise,with $0 \leqslant \chi < 1$ the price level is

[21]The markup is also assumed to be constant at steady state ($\mu = \frac{\xi}{\xi-1}$) in order to derive the equilibrium conditions.

[22]As shown by Bullard and Mitra (2003), this condition rules out eigenvalues on the unit circle.

[23]See Galí and Monacelli (2004) for a discussion on optimal policy in the foreign country and SOE cases.

I(0) and the condition (3.54) holds also in this case.

In the following sections we will first set the model parameters as calibrated to the Canadian economy, and before analyzing the welfare implications of each regime, compute the impulse response functions and second moment statistics .

3.3 Quantitative Results

3.3.1 Model Calibration

Baseline calibration of the model is based on recent literature and closely follows Galí and Monacelli (2004). The parameter values used by this study are intended to reflect Canadian data.

We use a labor supply elasticity of about $\frac{1}{3}$ which set $\phi = 3$ and a steady state markup $\mu = 1.2$ meaning that the elasticity of substitution between different domestic goods ξ is 6. The average price adjustment period by firms is set to 4 quarters and then we set the sticky price parameter ψ to 0.75, while the degrees of openness of the economy α is set to 0.4. The discount factor β is assumed to be equal to 0.99 and the elasticity of substitution between domestic and foreign goods θ takes the value 1.5 according to Backus et al. (1995), Galí and Monacelli (2004) use the special case where $\theta = \sigma = 1$.

The remaining parameters are somewhat difficult to determine. Indeed, there is no consensus among open economy researchers about the values attributed to the intertemporal rate of substitution σ, Cochrane (1997) uses values between one and two, Yun (1996) and Galí and Monacelli (2004) calibrate their models with $\sigma = 1$. We follow Erceg et al. (2000) and set this parameter to 1.5.

The calibration for the policy rule parameters follows Batini and Yates (2003) and Taylor (1993). We set ϕ_p and ϕ_y to 0.5 and as discussed in Batini and Yates the χ calibration is quite difficult. Indeed, using a range of values within the interval [0,1] the authors found that the optimal value of χ depends on the size of inflation tax, the cost of indexation and the length of nominal contracts. Following this study we set $\chi = 0.6$.

Moreover, following Galí and Monacelli (2004) and in order to calibrate the stochastic properties for labor productivity[24] (considered as a productivity shifter) and the stochastic properties of the exogenous variables we fit AR(1) processes to quarterly Canadian and US data[25] (ROW economy) over the period 1987Q01 - 2004Q04. We obtain the following estimates :

$$
\begin{aligned}
\hat{a}_t &= \underset{(0.09126)}{0.721194}\ \hat{a}_{t-1} + \varepsilon_{\hat{a},t}\ , \quad \sigma_a = 0.0088961 \\
\hat{a}_t^* &= \underset{(0.11769)}{0.569358}\ \hat{a}_{t-1}^* + \varepsilon_{\hat{a}^*,t}\ , \ \sigma_{a^*} = 0.0085895
\end{aligned}
$$

with standard errors in brackets. Finally the residual correlation is set to $corr(\varepsilon_{a,t}, \varepsilon_{a^*,t}) = 0.399211$. See Table 3.1 for a summary of model parameters calibration.

3.3.2 Impulse Response Functions and Second Moment Analysis

Impulse response functions (IRFs) play an important role in describing the impact that shocks have on economic variables. Figure 3.1 displays the impulse responses to a 1% positive technology shock under HT, IT and PT regimes.[26] The output gap response function has the same patterns for the HT and PT regimes, with an initial positive response of about 15% which then falls within the next two periods to reach negative values, and finally it reverts to steady state. The IRF under IT has the same initial response and then decreases to reach study state values within 5 periods. The inflation response (both domestic and CPI based inflation) displays the same patterns under the three policies we are targeting.

[24]Using the Canadian labor productivity for the period 1963Q01 - 2002Q04 as a proxy for domestic productivity, Galí and Monacelli (2004) estimate this to be : $\rho_a = 0.66$ with standard deviation of 0.0071.

[25]We use the productivity term constructed from the CANSIM series V719180 and V1409154, and the US productivity using the BLS series ID PRS30006092 retrieved from the Bureau of Labor Statistics web site.

[26]As discussed in monetary policy setting, we set $\chi = 1$ to compute the impulse responses under IT regime and $\chi = 0$, in order to get the responses under PT regime.

The main difference occurs on the initial response to shock which is positive for domestic inflation (about 2%) under the IT regime and negative for the other two regimes, with hump-shaped responses. CPI inflation has the same patterns under the three regimes, so that the monetary authority has the same response, stabilizing inflation under the three regimes when the technology shock occurs.

The nominal interest rate shows a different response. With an initial response to shock that is negative, it increases to attain a steady state in about 20 periods. Intuitively, this means that after the economy has been hit by a technology shock, the optimal monetary authority response will increase the nominal interest rate by a larger amount than the increase in inflation, resulting in an initial increase in the real interest rate level.

The terms of trade and net exports display similar paths, where initial positive responses and decreases reach steady state values persistently. This yields to a stationary behavior for those variables which defined as a property of the model. The nominal exchange rate moves in the wrong direction[27] with a persistent decline being more pronounced for PT and HT. The same patterns are displayed by the domestic and CPI price responses with a hump-shaped domestic price response under HT and PT. The unit root in the price level is then mirrored by the unit root in the exchange rate. However, the responses of those three variables are quite different during HT and PT targeting, where after a while the path reverts to initial values. The initial fall in the domestic and CPI price responses under HT and PT are followed by hump-shaped patterns (more pronounced for HT targeting) with a flat increase toward steady state values. Furthermore, the impact on foreign aggregates is negligible, by construction, implying that the world interest rate remains unchanged. There is an anticipated domestic currency appreciation induced by the uncovered parity (UIP). Thus, the exchange rate depreciation explains the paths followed by the inflation rates that jump up in the shock period and then revert back to initial levels.

[27]One can believe that monetary contraction generates appreciation for the domestic currency. Thus, capital outflows cause demand for foreign exchange to increase and not to fall, as is the case here.

The dynamic effects of foreign technology shocks are displayed in Figure 3.2. In this case, the foreign monetary authority reacts to shocks by lowering the world interest rate to stabilize inflation. The domestic authorities react in the same way by reducing their own interest rate to counterpart the real appreciation caused by the foreign policy,[28] followed by a gradual depreciation until both interest rates converge to their steady state levels.

Moreover, the output gap, domestic and CPI inflation responses display hump-shaped patterns for both HT and PT targeting. While terms of trade is more stable under HT and PT targeting, responses persistently remain above initial levels for this variable under IT targeting. The same patterns are displayed for net exports under the 3 regimes.

The fall in domestic and CPI prices is more accentuated with this shock under IT. The nominal interest rate response takes the hump-shaped form and then reverts to the initial value. The main difference between home and foreign technology shock responses is registered for the exchange rate while the response under all regimes persistently remains above the initial levels.

Finally the response functions of the macro variables to unit innovations in the policy shocks reveal that all variables display the same patterns under HT and PT targeting. However, the domestic and CPI price responses for levels under IT targeting are also persistently above the steady state levels. Interestingly, the figure shows persistent exchange rate responses slightly below the initial values for all regimes. This can be explained by the negligible effect of the policy innovations on foreign variables. Indeed, a rise in nominal interest rate is followed by an instant currency appreciation and an anticipated depreciation since the world interest rate remains unchanged. Asset and goods generate such movements in exchange rate and price levels.

In order to conclude the quantitative analysis, the second moments for some macro

[28] With our earlier assumption about the foreign monetary policy that stabilizes price levels at equilibrium, a reduction in world interest rate implies an appreciation of home currency.

variables under the three regimes are shown in Table 3.2. For each variable we report standard deviation.

The second moment analysis confirms the IRF visual analyses. Indeed, the IT regime requires more volatility in price levels and exchange rates than that shown under the other regimes. Terms of trade are more stable under HT, where their volatility is about eight times lower than that for the ITs. Intuitively, under IT price level should follow the I(1) process. Hence, price adjustment after the occurrence of shocks is carried out very sluggishly, leading to sluggish inflation behavior. In fact, lagged price levels have little direct influence on current price levels. In this case, the price adjustment made after shock occurrences inevitably entails sharp inflation fluctuation. Furthermore, the hybrid target can be set taking into account both inflation and its corresponding price level, such that past price levels affect current price levels, but their influence is not as strong as under IT. In this case, the price level path will lie between those under IT and PT. As pointed out by Kobayashi (2004), it can be said that implementing hybrid targeting can lead to relatively moderate inflation volatility by appropriately incorporating both the sluggish nature of inflation adjustment under IT and the rapid nature of inflation response under PT. More generally, and as shown in Galí and Monacelli (2004), we find that across regimes the higher the terms of trade volatility, the higher inflation and output gap volatility, and therefore the higher the resulting welfare score.

3.4 Welfare Analysis of Alternative Regimes

The analysis of welfare implications for different monetary policy rules has become an important field of study (Taylor, 1999). The main concern is how important it is for policy makers to have access to a set of tools that would allow them to predict the effects of switching from one policy rule to another. It would thus be worthwhile to investigate the welfare implications of the hybrid regime and compare them to other monetary policy targeting schemes considered in this work. The application of the quadratic approximation of the objective function is complex and cannot be simply derived in an open economy model with sticky prices. A popular measure thus uses inflation and output gap volatility, in addition to the utility function.

Furthermore, a welfare-maximizing central bank may target CPI inflation, CPI price or a combination of specific price and inflation paths. In fact, the key difference in approaches to inflation/price level targeting concerns a stable, long-run price level compared to maintaining a particular rate of inflation. These rule-based approaches have different welfare implications. Aoki (2001) and Devereux and Engel (2000) show that in a closed economy with sticky prices and backward-looking behavior, optimal policy entails the perfect stabilization of the inflation rate. In fact, Svensson (1999) shows that if monetary authority has a price-level targeting objective, then this may reduce inflation variability without affecting output variability. This 'free-lunch' result depends on substantial endogenous output persistence in the New-Classical Philips curve. Dittmar and Gavin (2000) extend this analysis to the case where expectations are forward-looking in a New-Keynesian Philips curve. They show that the free-lunch argument applies without the need for persistence terms. Thus, the assigning of a price level targeting objective by the central bank appears to improve welfare if expectations are forward-looking or if there is substantial endogenous persistence. Likewise, Vestin (2000) argues in a purely forward-looking model that price level targeting will provide more efficient outcomes than inflation targeting. In a closed economy model, Nessen and Vestin (2000) suggest that hybrid targeting will provide better outcomes than only targeting inflation, if the Philips cure has forward-and backward-looking components.

The evaluation of the household's welfare in the small open economy can be expressed as a fraction of steady state consumption. Indeed, following Galí and Monacilli (2004) we derive a second-order approximation to the domestic consumer utility function in a SOE model.[29] This second order approximation,[30] expressed as a fraction of steady state consumption, can be written as

$$\Xi = -\frac{(1-\alpha)}{2}\sum_{t=0}^{\infty}\beta^t[\frac{\xi}{\kappa}\hat{\pi}_{H,t}^2 + (1+\phi)\bar{x}_t^2]. \tag{3.55}$$

Hence, the welfare measure for our economy can be computed by taking the unconditional expectation of (3.55). The expected welfare losses of any policy in terms of domestic inflation and the output gap variances are then given by

$$\mathcal{F} = -\frac{(1-\alpha)}{2}[\frac{\xi}{\kappa}var(\hat{\pi}_{H,t}) + (1+\phi)var(\bar{x}_t)].$$

Using this expression we can compare different monetary policies to assess their welfare implications and highlight welfare cost among regimes.

Table 3.3 shows welfare losses associated with three different regimes : HT, IT and PT. We assume that central bank wants to minimize variations in domestic inflation ($\hat{\pi}_{H,t}$). Indeed, since most of the countries that use inflation targeting are likely to target CPI inflation rather than home inflation (namely producer price inflation), HT has been essentially compared to the CPI inflation targeting regime (IT in the text). Entries for loss functions are percentage units of steady state consumption.

There are five panels in this table. In the first panel, we report welfare losses under our benchmark calibration. The remaining panels display the effects of using different policy parameter (χ) values and of lowering, respectively, the degree of economy openness (α), and both the steady state mark-up (μ) and the elasticity of labour supply (ϕ).

[29]See Appendix 4 in Galí and Monacelli (2004) for details on the welfare loss function derivations. However, the derivation is restricted to the special case of log utility and unit elasticity of substitution between different goods (i.e., $\sigma = \eta = \theta = 1$) in deriving an exact expression, otherwise, its derivation is more complicated. We use this approximation for comparison purpose between different regimes without loss of generality. For more discussion about welfare analysis in the loglinearized model, refer to Kim and Kim (2003) and Schmitt-Grohe and Uribe (2004).

[30]After dropping terms independent of policy and those of high order.

The results show that under our benchmark parametrization, the reduction in welfare loss results from a decrease in output and domestic inflation volatility varying from IT to HT regime. On the other hand, the CPI inflation targeting leads to a level of losses in the welfare loss function much higher than that obtained by the two other regimes. In fact, as usually found in the literature,[31] welfare losses are quantitatively small for all regimes.

As compared to the benchmark case, and using different policy parameter, the HT regime implies substantially larger welfare losses as one gets closer to extreme values corresponding either to IT or PT. We next consider the effect of lowering the degree of economy openness. This has a general effect of decreasing both domestic inflation and output gap volatilities leading to low welfare losses under all regimes. Intuitively, this means that the decrease in volatilities and the resulting welfare values are essentially generated by movements in small open economy variables such as terms of trade and exchange rate which have low effects in a 'quasi-open economy' (with small α). Also in this case, HT delivers lower welfare losses than PT and IT regimes.

Finally, we explore the effects of lowering both the mark-up to 1.1, which leads to a larger penalization of inflation variability in the loss function, and the elasticity of labour supply to 0.1, which implies a larger penalization of output gap volatility. This leads to a similar output gap volatility compared to the other scenarios considered here, and in turn to an amplification of the volatility of the domestic inflation which implies higher welfare losses for all three regimes. Interestingly, the HT regime leads to larger welfare losses than IT and PT meaning that the results may be sensitive to the model assumption as pointed out by Galí and Monacelli (2004) and Schmitt-Grohé and Uribe (2001).[32]

Moreover, in closed-economy models the case for price stability is quite robust. Its desirability is associated with the possibility of reproducing the fluctuations that would

[31]Kollman (2002) and Smets and Wouters (2003) are recent examples of papers where monetary policy welfare implications are investigated for a small open economy.

[32]The authors argue that the welfare ranking between different monetary policy may be sensitive to the distortions in the economy.

arise in a flexible-price world which produces higher welfare gain (see for instance Goodfriend and King, 2001). In the open economy models, the different dynamics of the terms of trade are associated with a welfare loss, relative to the monetary policy regime. Indeed, as shown in the quantitative evaluation of the second moments conducted above, the terms of trade dynamics imply a substantially larger deviation on the welfare function as the associated volatility increases. Intuitively, this can lead to different results if the open economy analysis is adopted to assess welfare-maximizing monetary policy.

3.5 Concluding Remarks

This chapter investigates the hybrid inflation/price-level targeting from a New-Keynesian perspective. To this end, we calibrate generalizations of the models proposed by Galí and Monacelli (2004) and Monacelli (2003) to the Canadian economy. Both papers develop a small open economy model incorporating many of the microfoundations appearing in a closed economy within the New-Keynesian framework (see, for instance, Clarida, Galí, and Gertler, 2000 and Woodford, 2003) as was recently used for the analysis of monetary policy. The model's open economy version allows for the possibility that international trade in goods and financial assets would affect the evolution of the domestic economy, thus giving rise to richer dynamics within the model, including our assumption of complete securitie markets.

Furthermore, in light of the considerable attention given in recent macroeconomic literature to monetary policy formulations in terms of interest rate rules, we adopt this formulation to construct three regimes. In addition, for the purpose of comparison to the hybrid regime, we analyze the IT and PT regimes. Our results show that hybrid targeting can lead to a successful monetary policy strategy, yet without any major loss in the welfare function. Likewise, in this kind of model, including more nominal rigidities, particularly sticky wages or some type of indexation would be expected to change results obtained in a crucial manner. Further research is therefore necessary in order to establish the manner in which these frictions would likely alter this finding.

Tab. 3.1: Model Calibration

Parameters	Values assigned
μ	1.2
ϕ	3
ξ	6
θ	1.5
σ	1.5
α	0.4
ψ	0.75
χ	0.6
ϕ_p	0.5
ϕ_y	0.5
ρ_A	0.72
ρ_{A^*}	0.57
σ_A	0.00889
σ_{y*}	0.00859
σ_r	0.50

Tab. 3.2: Volatility Under Alternative Policy Regimes
(Standard Deviations in %)

	HT Regime	IT Regime	PT Regime
Output Gap	0.445706	0.504724	0.586738
Domestic Inflation	0.249263	0.279909	0.261040
CPI Inflation	0.357693	0.591798	0.329794
Nominal Interest Rate	0.290764	0.355671	0.281302
Exchange Rate	16.51607	16.51058	16.29682
CPI Price Level	0.549267	14.36523	0.352878
Domestic Price Level	1.365590	23.58970	1.237270
Terms of Trade	3.025147	23.68741	3.035614

Tab. 3.3: Welfare Losses Under Alternative Policy Regimes

	HT Regime	IT Regime	PT Regime
Benchmark $\mu = 1.2, \phi = 3, \alpha = 0.4$ and $\chi = 0.6$			
Var(Domestic Inflation)	0.062132	0.078349	0.068142
Var(Output Gap)	0.198653	0.254746	0.344262
Welfare Loss ($\mathcal{F}$)	-1.541324	-1.948742	-1.842111
$\mu = 1.2, \phi = 3, \alpha = 0.4$ and $\chi = 0.25$			
Var(Domestic Inflation)	0.073787	0.078349	0.068142
Var(Output Gap)	0.233661	0.254746	0.344262
Welfare Loss ($\mathcal{F}$)	-1.827778	-1.948742	-1.842111
$\mu = 1.2, \phi = 3, \alpha = 0.4$ and $\chi = 0.85$			
Var(Domestic Inflation)	0.082347	0.078349	0.068142
Var(Output Gap)	0.187444	0.254746	0.344262
Welfare Loss ($\mathcal{F}$)	-1.729144	-1.948742	-1.842111
Low degree of openness $\mu = 1.2, \phi = 3, \alpha = 0.25$ and $\chi = 0.6$			
Var(Domestic Inflation)	0.034906	0.050817	0.042506
Var(Output Gap)	0.082783	0.026711	0.123046
Welfare Loss ($\mathcal{F}$)	-1.039187	-1.372176	-1.298804
Low steady state mark-up and elasticity of labour supply $\mu = 1.1, \phi = 10, \alpha = 0.4$ and $\chi = 0.6$			
Var(Domestic Inflation)	0.312197	0.184993	0.195961
Var(Output Gap)	0.181364	0.095449	0.122008
Welfare Loss ($\mathcal{F}$)	-7.145550	-4.194459	-4.512109

Fig. 3-1: Impulse Response Functions to a Unit Shock in Home Tech. Innovations

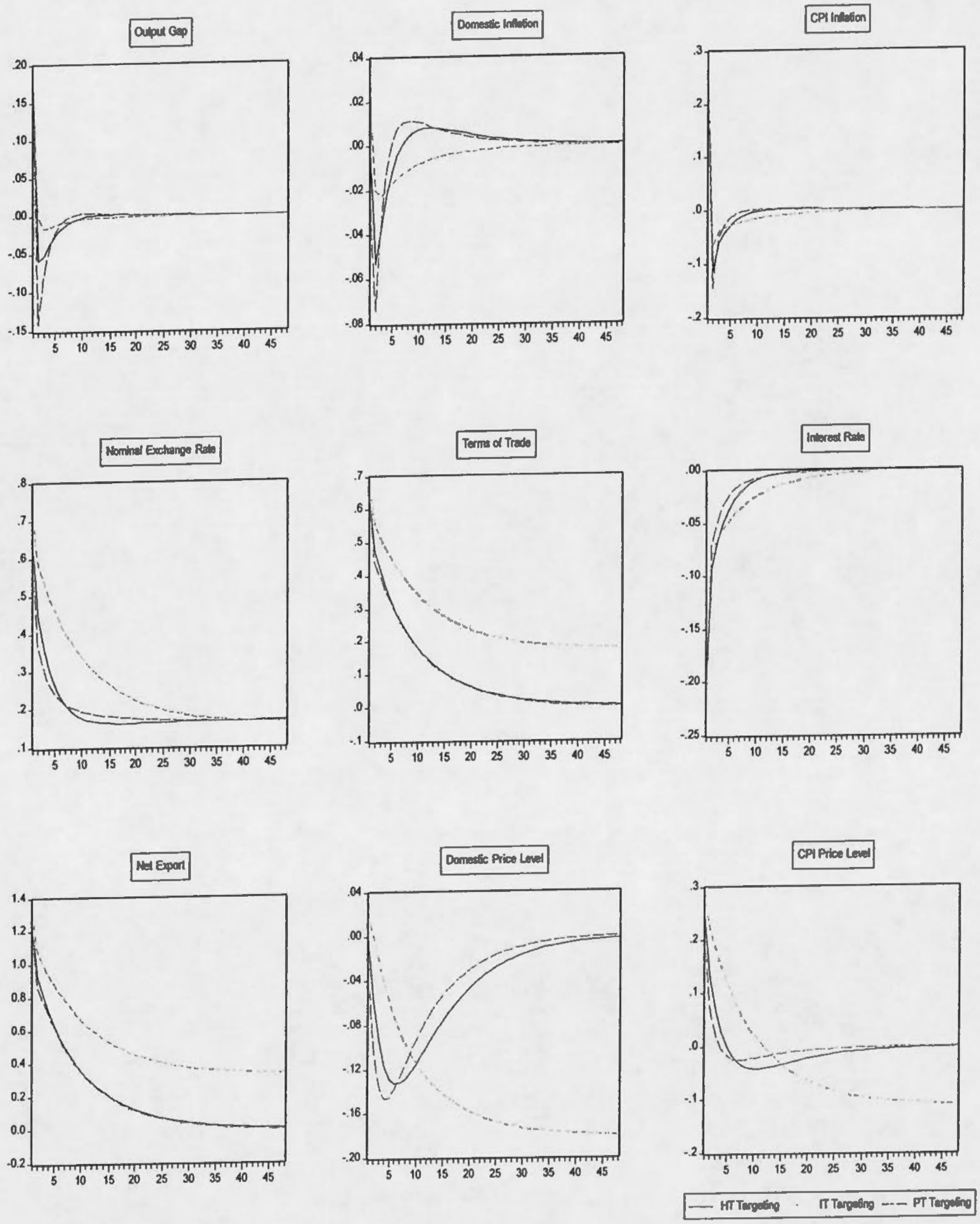


Fig. 3-2: Impulse Response Functions to a Unit Shock in Foreign Tech. Innovations

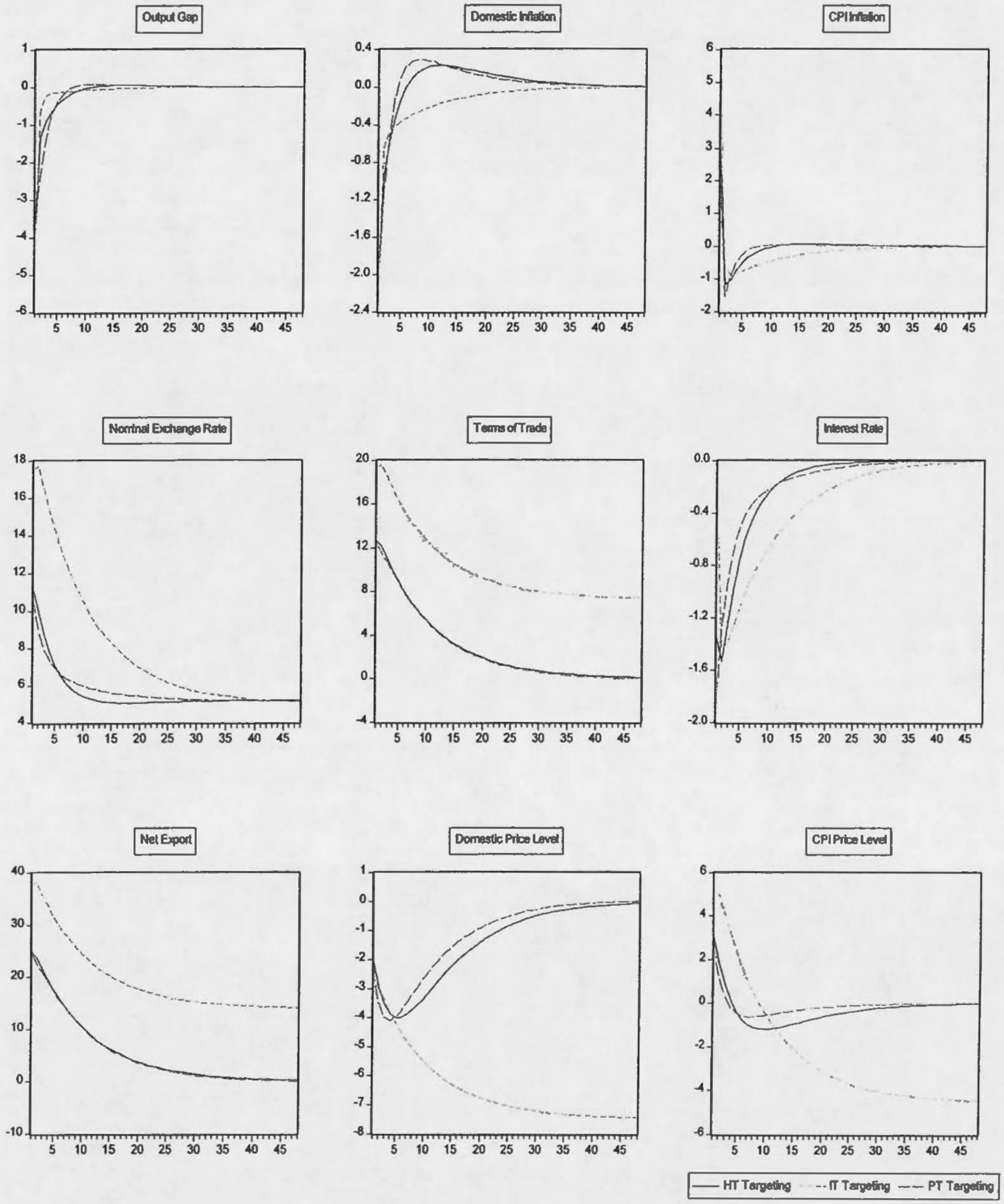
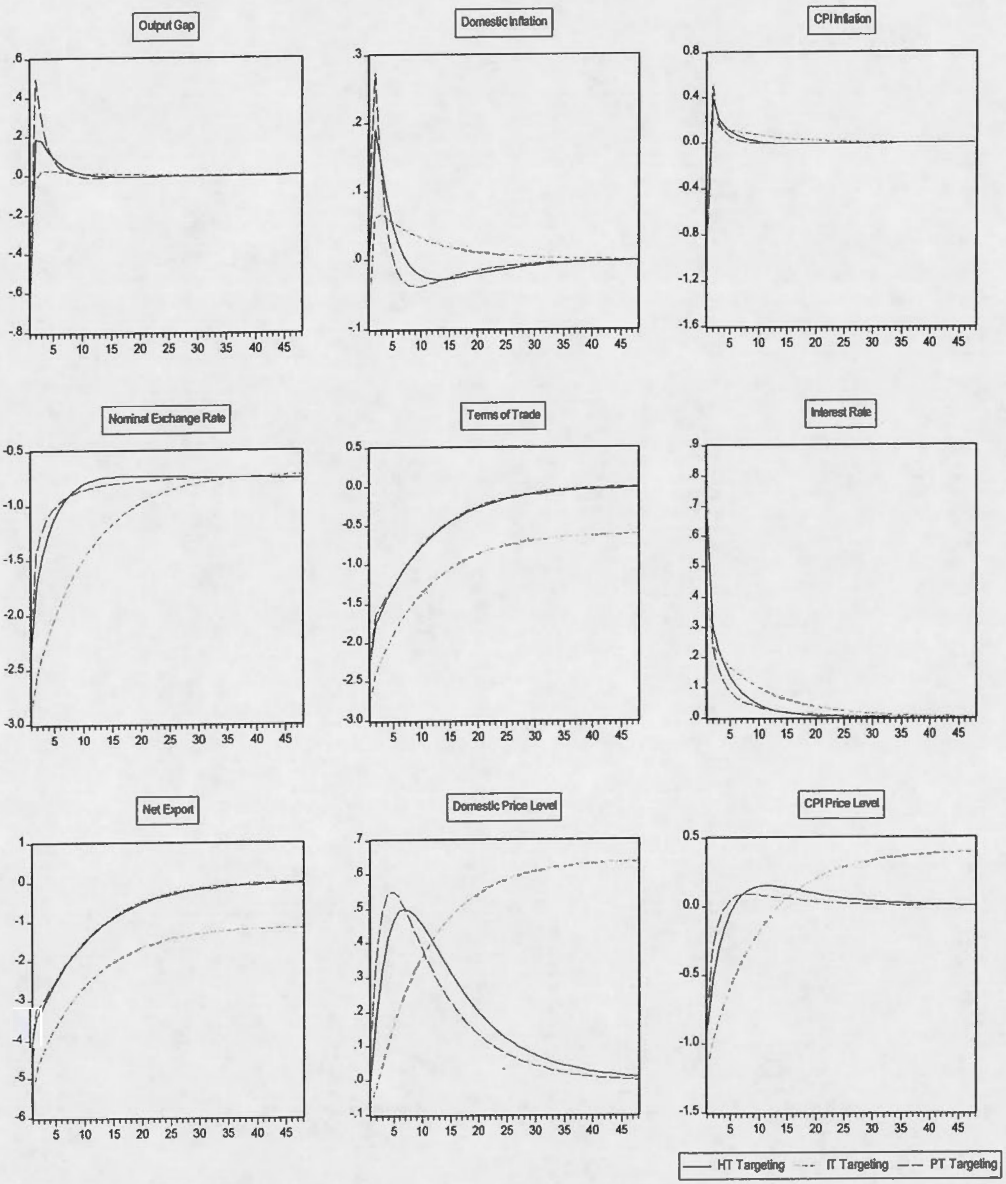


Fig. 3-3: Impulse Response Functions to a Unit Shock in Interest Rate Rule Innovations



APPENDICES

Annexe A Model Setting

A.1 Household's Problem

The household maximizes

$$E_t \sum_{j=0}^{\infty} \beta^j [\frac{(C_{t+j} - X_{t+j})^{1-\gamma_1}}{1-\gamma_1}],$$

subject to the following constraint

$$X_t = bC_{t-1}$$

and the budget constraint

$$P_t^f B_{t+1} + P_{t+1}^e A_{t+1} + (1+\kappa_t)^{-1} P_t^{f*} B_{t+1}^* + C_t \leqslant W_t n + B_t + B_t^* + (P_t^e + D_t) A_t. \qquad (\Lambda_t)$$

where P_t^e , P_t^f and P_t^{f*} denote the prices of the risky asset, the home and foreign riskless bond respectively. At time t, the equity pays a dividend payout D_t and each bond pays one unit of the consumption good at time t+1 and expires. Here that κ_t is expressed as

$$\kappa_t = \exp(-\frac{\varphi \tilde{B}_t^*}{Y_t}),$$

We can introduce the first equation directly in the utility function. Thus the controls in this economy are : C_t, B_{t+1}, $B_{t+1,}^* A_{t+1}$.

A.2 Firm's Problem

The manager of the firm maximize the value of the firm to its owners

$$E_t \sum_{j=0}^{\infty} \beta^j \frac{\Lambda_{t+j}}{\Lambda_t} \{Z_{t+j} K_{t+j}^{\alpha} (X_{t+j} n_{t+j})^{1-\alpha} - W_{t+j} n_{t+j} - I_{t+j}\}$$

subject to the following constraints

$$K_{t+1} = (1-\delta)K_t + (\frac{a_1}{1-\xi}(\frac{I_t}{K_t})^{1-\xi} + a_2)K_t, \quad 0 < \delta < 1.$$

$$Y_t = Z_t K_t^{\alpha} {n_{t+j}}^{1-\alpha},$$

where $\beta^j \frac{\Lambda_{t+j}}{\Lambda_t}$ is the marginal rate of substitution of the household and n_t the quantity of labor input. The state of technology evolves according to the AR(1) process

$$Z_t = \exp(Z_{t-1}) \text{ or in log} : z_t = \rho_z z_{t-1} + \epsilon_{zt},$$

with z_{-1} given and ϵ_{zt} is a normally distributed white noise with mean 0 and variance σ_z^2 for all $t \geqslant 0$. The controls here are :I_t, n_t .

A.3 Other Equations of the Model

The dividends equation is given by

$$D_t = Y_t - W_t n_t - I_t$$

The resources constraint equation

To compute the resources constraint equation we can set $B_t = 0$ and we normalize $A_t = 1$. The budget constraint can then be written as

$$P_{t+1}^e + {\kappa_t}^{-1} P_t^{f*} B_{t+1}^* + C_t \leqslant W_t n + B_t^* + (P_t^e + D_t)$$

and we know that

$$D_t + W_t n_t = Y_t - I_t.$$

At equilibrium the strict equality holds, that is the resource constraint can be written as

$$B^*_{t+1} - B^*_t = Y_t - C_t - I_t - \Delta P^e_{t+1} \; - ((1+\kappa_t)^{-1} P^{f*}_t - 1) B^*_{t+1}$$

The production function is given by

$$Y_t = Z_t K^{\alpha}_t {n_{t+j}}^{1-\alpha}.$$

From the law of motion of capital one can isolate the term of investment

$$I_t = [(\frac{K_{t+1}}{K_t} - 1 + \delta - a_2)\frac{(1-\zeta)}{a_1}]^{\frac{1}{1-\zeta}} K_t.$$

A.4 Log-linearization of the Model

We define the variables without t subscripts as steady-state values and the variables with circumflex as a percentage deviation of the variables from their steady states. For example, $\hat{C}_t = (C_t - c)/c$ denotes the percentage deviation of consumption from its steady state (c).

Linearizing the first-order conditions yields

$$\frac{\gamma_1 \beta b}{(1-b)(1-\beta b)} E_t \hat{C}_{t+1} = \frac{\gamma_1(\beta b^2 + 1)}{(1-b)(1-\beta b)} \hat{C}_t - \frac{\gamma_1 b}{(1-b)(1-\beta b)} \hat{C}_{t-1} + \hat{\Lambda}_t,$$

$$\beta \hat{\lambda}_t + P^f \hat{P}^f_t = \beta E_t \hat{\Lambda}_{t+1},$$

$$P^e\hat{P}_t^e + \beta DP^e\hat{\Lambda}_t = \beta DP^e E_t\hat{\Lambda}_{t+1} + \beta DP^e E_t\hat{D}_{t+1} + \beta DP^e E_t\hat{P}_{t+1}^e$$

$$P^{f*}\hat{P}_t^{f*} + \beta(1+\kappa)\hat{\Lambda}_t - \beta\kappa\hat{\kappa}_t = \beta(1+\kappa)E_t\hat{\Lambda}_{t+1}$$

$$\begin{aligned}
\zeta(\frac{I}{k})^{\zeta}\hat{k}_t - \zeta(\frac{I}{k})^{\zeta}\hat{I}_t + \beta\alpha a_1 n^{1-\alpha}k^{\alpha-1}\hat{Z}_{t+1} \quad = \quad & [\beta\zeta(1-\delta+\frac{a_1}{1-\zeta}(\frac{I}{k})^{1-\zeta}+a_2)(\frac{I}{k})^{\zeta} - \beta\alpha a_1(\alpha-1) \\
& Zk^{\alpha-1}n^{1-\alpha}]\hat{K}_{t+1} - \beta\zeta[1-\delta+\frac{a_1}{1-\zeta}(\frac{I}{k})^{1-\zeta} \\
& +a_2)(\frac{I}{k})^{\zeta}]\hat{I}_{t+1} + \beta[\alpha a_1 ZK^{\alpha-1}n^{1-\alpha} - a_1\frac{I}{K} \\
& +(1-\delta+\frac{a_1}{1-\zeta}(\frac{I}{k})^{1-\zeta}+a_2)(\frac{I}{k})^{\zeta}]E_t\hat{\Lambda}_{t+1} \\
& -\beta[\alpha a_1 ZK^{\alpha-1}n^{1-\alpha} - a_1\frac{I}{K} + (1-\delta \\
& +\frac{a_1}{1-\zeta}(\frac{I}{k})^{1-\zeta}+a_2)(\frac{I}{k})^{\zeta}]\hat{\Lambda}_t
\end{aligned}$$

$$\alpha\hat{K}_t + \hat{Z}_t = \hat{W}_t,$$

And finally, the linearization of the identities yields

$$\hat{K}_{t+1} = [1-\delta-a_1\frac{\zeta}{1-\zeta}(\frac{I}{K})^{1-\zeta}+a_2]\hat{K}_t + a_1(\frac{I}{K})^{1-\zeta}\hat{I}_t$$

$$\hat{\kappa}_t = -\frac{\varphi B^*}{Y}B_t^* + \frac{\varphi B^*}{Y}\hat{Y}_t,$$

$$\hat{Y}_t = \alpha\hat{K}_t + \hat{Z}_t$$

$$D.\hat{D}_t = Y.\hat{Y}_t - nW.\hat{W}_t - I.\hat{I}_t$$

$$Y.\hat{Y}_t = C.\hat{C}_t + I.\hat{I}_t$$

The tech. shock process is linearized to

$$z_t = \rho z_{t-1} + d\varepsilon_t,$$

Finally, as shown by Jermann (1994), the leisure does not enter utility function, so Agents will allocate their entire time endowment to productive work (Fixed Labor Economy). In this framework n is fixed to it's steady state value (n=0.33).

Annexe B Data Appendix

Data Sources and Definitions of Variables

All macro data series are monthly and cover the period 1960M01 to 2000M12. The new measure of monetary shock is monthly and covers the period 1969M01 to 1996M12 (retrieved from Romer and Romer, 2004). To avoid the complications introduced by the seasonal adjustment methods, the data we use here are in their non seasonally adjusted forms and we include monthly seasonal dummy in our VARs.

- The industrial production data, used as output series (Y), are from the Board of Governors Web site (series B50001).

- Consumer price index, all urban consumers are used as our price (P), from the Bureau of Labor Statistics Web site (series CUUR0000SA0).

- The three-month Treasury bill rate used as short term interest rate (R3), quoted on discount basis, secondary market, average of business day, from Federal Reserve Board (Bank of St-Louis Web site), (series tbsm3m).

- Ten-year U.S Treasury bond yield used as long term interest rate (R10), constant maturity, average of business day figure, from Federal Reserve Board (Bank of St-Louis Web site), (series tcm10y).

- For Total reserves (TR), we use Board of Governors Monetary Base, Not Adjusted for Changes in Reserve Requirements, from Board of Governors of the Federal Reserve System (series BOGUMBNS).

- Producer Price Index-Commodities, crude materials is used as commodity prices (PCM), from the Bureau of Labor Statistics Web site (series WPUSOP1000).

Annexe C Technical Appendix

Statistic Tests Computation

LR Test :

The likelihood ratio has an asymptotic χ^2 distribution with degrees of freedom equal to the number of restrictions. The formula[33] used to compute the LR test is

$$LR = (T-m)(\log(|\hat{\Omega}_r|) - \log(|\hat{\Omega}_u|)) \sim \chi^2(n),$$

with T is the number of observations, m is the number of parameters estimated (per equation) in the unrestricted model, $|\hat{\Omega}|$ is the natural logarithm of the residual covariance's determinant (computed for the restricted and unrestricted models), and n the number of restrictions in the VAR. The determinant of the residual covariance is computed as

$$|\hat{\Omega}| = \det(\frac{1}{T-m}\sum_t \hat{\epsilon}_t\hat{\epsilon}_t').$$

When the log likelihood value is computed assuming a multivariate normal (Gaussian) distribution as

$$l = -\frac{T}{2}\{k(1+\log 2\pi) + \log(|\hat{\Omega}|)\}.$$

Information Criteria :

The two information criteria are computed as follow

$$AIC = -2(\frac{l}{T}) + 2(\frac{m}{T}),$$

$$SIC = -2(\frac{l}{T}) + m\log(T)/T,$$

where m is the number of parameters estimated using T observations.

[33]This Formula employs Sims' (1980) small sample modifications which uses (T-m) rather than T (see Lütkepohl, 1991).

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